An investigation into the use of intensive therapy, with and without Constraint-Induced Movement Therapy, in South African children with hemiplegia.

Submitted in fulfilment of the requirements of the Masters of Science Degree in Physiotherapy - 2005

University of Cape Town

Researcher:

Esther Geretto

Supervisors:

Associate Professor Jennifer Jelsma

Dr. Brenda Morrow

Declaration

I, Esther Geretto, hereby declare that the work on which this dissertation is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

I empower the university to reproduce for the purpose of research either the whole or any portion of the contents in any manner whatsoever.

Signature:.....

Date:.....

Abstract

This research project aimed to determine whether a two week period of intensive physiotherapy in groups, using the Neurodevelopmental Approach or Constraint Induced Movement Therapy (CIMT), would result in a functional improvement in the hand function of children with hemiplegia. It also aimed to determine if group CIMT was more effective than group physiotherapy based on the Neurodevelopmental (NDT) approach. The feasibility of CIMT in the South African context was also investigated

Sixty-five children with hemiplegia were requested to participate in the research study at the Red Cross Children's Hospital in Cape Town, South Africa. Twelve of these patients eventually participated in the study. They were divided into CIMT and NDT based physiotherapy groups. Both groups received intensive physiotherapy for a period of two weeks (every day for two hours). The non-affected upper limb of the CIMT group was restrained with a glove, whilst the NDT based physiotherapy group was unrestrained.

The children were assessed before therapy, directly after therapy at two weeks, using the Peabody Developmental Fine Motor Scale and kinematic analysis (Vicon Clinical Manager), and again one month later using the Peabody Developmental Fine Motor Scale. The results showed that the children (in both the CIMT and NDT-based physiotherapy groups) demonstrated a significant improvement in grasp function (with a change in median grasp score from 28.5 to 33.0, $p<0.02$) and visual motor integration (with a change in median VMI score from 71.0 to 78.0, $p<0.02$) following two weeks of intensive physiotherapy and that this improvement in function was maintained for a month following therapy. There did not appear to be any benefit of group CIMT over that of NDT based physiotherapy – however this is said with caution due to the small sample size.

Through the questionnaire and informal interviews, it was felt that CIMT in its' current form was not feasible for use in the South African context, mainly due to lack of financial and human resources. Further research is recommended to determine whether a different mode of CIMT therapy would be more feasible in the South African context. However, it was felt

that due to the improvement seen after two weeks of group intensive physiotherapy, an attempt should be made to integrate periodic sessions of intensive group therapy into local community settings, particularly in the South African context of inadequate resources, to provide regular therapy to children living in rural areas.

Acknowledgements

Esther Geretto would like to acknowledge Brenda Morrow and Jennifer Jelsma for their support and hard work in the supervision of this dissertation.

Thanks to the children and families of Red Cross Children's Hospital (RCWMCH) in Cape Town for participating in the research trial. To the RCWMCH physiotherapy staff - most especially Liza Lucani, Cara Le Roux, Sameer Rahim and Adilah Rasdien for their help in facilitating the physiotherapy sessions. Thanks to Edith Moneleki for her hours of interpretation.

Thanks also to the team at the UCT Sports Science Institute – Prof Vaughan, Lianne Berett and Tamara Stew, for all their help with the kinematic analysis. Thank-you also to Greg Distiller, consultant statistician at UCT, for his help with the statistics.

Thanks to the, Institute of Child Health, University of Cape Town and the South African Physiotherapy Association for funding the research project.

Esther Geretto would also lastly like to thank her husband Marco for all his encouragement, love and support throughout the research.

Table of contents

Contents of tables

Contents of figures

Glossary

Acquired hemiplegia - Acquired cerebral palsy is associated with damage or abnormality after labour until two years of age (Arens et al, 1978).

Cerebral palsy – Cerebral palsy describes a group of disorders of the development of movement and posture, causing activity limitations that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain. The motor disorders of cerebral palsy are often accompanied by disturbances of sensation, cognition, communication, perception, and/or behaviour, and/or by a seizure disorder (United Cerebral Palsy Research, 2004.)

Congenital hemiplegia - Congenital causes which are associated with conception, fetal development or the birth process (Arens et al, 1978).

Constraint-Induced Movement Therapy (CIMT) – Therapy involving restraining the non-affected hand and facilitating the use of the hemiplegic upper limb (Taub, 2004).

CIMT group – For the purpose of this research, this describes the children who are wearing the CIMT strapping device and undergoing group physiotherapy based on CIMT principles (Primary investigator's description).

Fine motor quotient of the PDFMS – A composite of the results of the two subtests (visual motor integration and grasp test) that measure the use of the hand muscles. (Folio and Fewell, 2000).

Hemiplegia – Children with cerebral palsy who have one side of the body affected more than the other side of the body (Bobath and Bobath, 1975).

Hypertonia – An abnormally increased resistance to externally imposed movement about a joint. It may be caused by spasticity, dystonia, rigidity or a combination of these features (NINDS workshop, 2001).

Intensive physiotherapy – For the purpose of this research, this is described as two hours per day of physiotherapy for two weeks and includes both the CIMT and NDT based physiotherapy groups (Primary investigator's description).

Muscle tone – The tension between the origin and insertion of each muscle. (Howe and Oldham, 1995).

NDT based physiotherapy group – For the purpose of this research, this describes the children who are receiving group physiotherapy based on the Neurodevelopmental Approach and are not wearing the CIMT strapping device (Primary investigator's description).

Peabody Fine Motor Developmental Scale (PDFMS) – A norm-referenced standardized test that is used to assess the gross- and fine- motor development of children between the ages of 0 to 83 months (Folio and Fewell, 2000).

Spasticity – Spasticity is a velocity dependent resistance of a muscle to stretch (NINDS workshop, 2001).

Abbreviations

AAUT	Actual Amount of Use Test
AMAT	Arm Mobility Ability Test
AS	Arm Sling
CIMT	Constraint-Induced Movement Therapy
CP	Cerebral palsy
CT	Computed tomography
DMQ	Developmental Motor Quotient
FMQ	Fine Motor Quotient
IVH	Intraventricular Haemorrhage
MCP	Metacarpophalangeal
MU	Movement unit
NDT	Neurodevelopmental Therapy
PDMS	Peabody Developmental Motor Scale (includes fine and gross motor scale)
PDFMS	Peabody Developmental Fine Motor Scale
PMAL	Paediatric Motor Activity Log
RCWMCH	Red Cross War Memorial Children's Hospital
RHS	Resting Hand Splint
SD	Standard Deviation
Tx	Treatment
TBM	Tuberculosis meningitis
VMI	Visual Motor Integration
VCM	Vicon Clinical Manager

Chapter One: Introduction

1.1 Background

A large proportion of the South African population live in poor socio-economic conditions, with the associated problems of poverty, poor access to healthcare facilities and lack of sanitation and housing. These conditions lead to insufficient perinatal care for mothers and result in large number of children being born with cerebral palsy (Thompson, Buccimazza, Webster, Malan and Molteno, 1993; Arens, Molteno, Marshall, Robertson and Rabkin, 1978). In the Western Cape, over 2000 children with cerebral palsy (CP) are currently being managed by therapists working under the auspices of the Western Cape Cerebral Palsy Association. However the total number of children in the Western Cape affected with CP is not known. Of the 2549 children with CP seen from June 2003 to August 2004, 43% were between the ages of two and five years (Western Cape Cerebral Palsy Association, 2004).

At Red Cross War Memorial Children's Hospital (RCWMCH) in Cape Town, South Africa, a large number of children with CP are managed and treated. RCWMCH is a publicly funded academic hospital which manages a large number of indigent patients, mostly from the Western Cape region. Neurodevelopmental Therapy (NDT), as described by Bobath and Bobath (1975), is a widely used medium of assessment and management of CP at the institution. The majority of RCWMCH patients receive therapy once a month as most caregivers cannot afford the cost of public transport from their home to the hospital. In addition to the expense of this transport, many caregivers forfeit a day's salary to enable their child to receive therapy (Huskisson, 1998). As a result of these concerns, direct hands-on therapy is limited. Instead, the caregiver is instructed in ways of managing, handling and positioning the child at home. Where possible and applicable, group therapy sessions are also conducted, with the parent or caregiver performing the direct patient facilitation under the direction and supervision of a physiotherapist (Asha Parbhoo, personal communication, 2004).

Although some authors have indicated that individualized NDT is effective in improving the function of children with cerebral palsy (Knox and Evans, 2002; Bower and McLellan, 1992; Kluzik, Fetters and Coryell, 1990), very little research has been conducted within the context of a developing country in this regard. To the primary investigator's knowledge, no research has been conducted investigating the efficacy of group NDT treatment or the benefits of home treatment programmes in the South African context. There is still a great need for further research to determine the efficacy of NDT (Butler and Darrah, 2001; Ottenbacher and Jannell, 1993; Ernst, 1990) specifically for children with hemiplegia where the evidence supporting the benefits of NDT is particularly poor.

In the context of a resource-limited health-care facility serving an impoverished community, it is essential to optimise the time spent in physiotherapy as well as the efficacy of the intervention.

Constraint-induced movement therapy (CIMT) has recently been proposed as a treatment option aimed at improving upper limb function in children with hemiplegia living in First World settings (Eliasson, Krumlinde-Sundholm, Shaw and Wang, 2005; Taub, Ramsey, De Luca and Echols, 2004; Willis, Morello, Davie, Rice and Bennet, 2002). Although the results of the initial childhood trials are not conclusive, mainly due to small sample sizes, the treatment has appeared to result in a favourable outcome.

This study, therefore, aimed firstly to investigate the efficacy of a two week period of intensive group physiotherapy using either NDT based physiotherapy or CIMT and, secondly, to investigate the feasibility and efficacy of CIMT in a developing world environment; in the hope of identifying an effective treatment modality for children with hemiplegia. If group NDT based physiotherapy and/or CIMT could be implemented and developed to cater for children in this setting and proved to be effective in improving their function, then this could be incorporated into physiotherapy treatment programs at RCWMCH, and elsewhere in South Africa.

1.2 Research aims and objectives

1.2.1 Research Aim

The aim of this pre-experimental investigation was to investigate the immediate and mid-term (one month post intervention) effects of an intensive two-week course of group physiotherapy using either NDT or CIMT principles, on children with hemiplegia between the ages of two to five years, in the South African context.

A randomised control experimental design was used to investigate the differences between NDT and CIMT physiotherapy. However, when investigating the effects of an intensive two-week course of therapy (combining both groups of patients), no control group was used (i.e. there was no "restricted/withdrawn therapy" group) as it is considered unethical to deny treatement to patients for the purposes of research. As a result even though causality was investigated it was not possible to prove that the intensive therapy intervention was in fact responsible for the changes that occurred.

1.2.2 Research objectives

The objectives of this study were to:

1. determine if there was an overall improvement in hand function after two weeks of intensive group physiotherapy using either NDT or CIMT principles, and whether this is maintained at one month after therapy;

2. determine the immediate and mid-term effect of two weeks group CIMT compared to two weeks of group NDT based physiotherapy, on raw- and age-adjusted Peabody Developmental Fine Motor Scale (PDFMS) scores;

3. determine whether there is a significant difference in the number of movement units and compensatory strategies of reaching between children who have had two weeks of group CIMT and those who have had group NDT based physiotherapy;

4. determine whether variables such as side of hemiplegia, congenital or acquired lesions, age of acquired hemiplegia and gender of the child are predictive of changes in the PDFMS scores, number of movement units and compensatory strategies of reaching in children who had received two weeks of intensive physiotherapy;

5. determine how the children and their parents/caregivers perceive the use of CIMT; and

6. investigate the feasibility of using group CIMT in the South African context.

Chapter Two: Literature review

2. 1 Introduction

The aims of this literature review were the following: Firstly, to gain increased knowledge in areas that were relevant to this research and to use this knowledge to conduct appropriate forms of therapy for children with children with hemiplegia. Secondly, it was also used to determine what paediatric physiotherapy and CIMT studies had previously been undertaken in order to allow for the most appropriate method of research to be conducted in the South African context, and at the same time allow for comparisons between this research and other published findings. Thirdly, it was used to investigate various paediatric assessment tools, which enabled the primary investigator to determine which assessment tool would be the most effective in this research project. And lastly, the literature review was used to determine the most effective methodology for the study.

In order to investigate and to debate the use of various treatment methods in children with hemiplegia, one first needs to understand the functional difficulties that children with hemiplegia experience. However, in order to determine the underlying functional problems in children with hemiplegia, it is important that one understand normal childhood development.

This literature review will therefore first discuss the normal development of children within the prescribed age group (two to five years). For the purpose of this research, the normal development of hand function, play and the process of learning will be discussed. Once normal development has been described, the literature review will give a general overview of cerebral palsy and then specifically focus on the development and underlying problems of the child with hemiplegia.

The development and motor learning of the child with hemiplegia, the various methods of treatment for children with hemiplegia will then be discussed. This review will only cover those areas which are relevant to the study and will therefore discuss NDT and CIMT. Thereafter, the instrumentation that is used to assess the effectiveness of treatment will be discussed.

Lastly, the outcome that the literature review had on the implementation and methodology of the study will be mentioned.

2.1.1 The method of the literature review

Searches were conducted using "PubMed", "Cochrane Library", the University of Cape Town's search engine "Alpha", "PEDro" (Physiotherapy Evidence Database), "HILO" North West London Hospital search engine and "Google.com". References were also reviewed from articles that were published.

The literature search covered many topics, with the focus being any article that cited CIMT, NDT, the Bobath Approach; Motor learning; Hemiplegia, Peabody Developmental Motor Scale and Cerebral Palsy. Modifying terms such as "paediatric", "children", "South Africa", and "Cape Town" were used.

2.2 Normal Development of Hand Function

An understanding of the normal development of a child is necessary to determine the underlying functional problems in children with CP. The discussion of normal development focuses on the development of hand function in children within the prescribed age group (two to five years), according to the specific aims of this study. It also describes the development and importance of play in this age range, as this is a vital component of effective physiotherapy for children with hemiplegia. For clarity in this discussion the patient will be referred to as "he" and the therapist will be referred to as "she."

2.2.1. An overview of the development of hand function

"Hands are the tools most often used to accomplish work, to play and to perform self-maintenance tasks" (Exner, 2001, 289). Hand function is dependent on gross motor function (such as establishment of head, trunk and pelvic control), cognitive function, sensorimotor and visual-perceptual fine motor function (Levitt, 1995; Case-Smith, 1994; Erhardt 1994; Exner, 1989).

The range of joint motion and tone of the upper limb are factors that determine the development of hand function. The range of motion of the upper extremity has a significant effect on positioning the arm for hand use and for reaching and grasping skills. Tone abnormalities affect the range of movement of joints in the upper extremity and will decrease the speed and of the upper limb during functional activities (Exner, 1989).

Cultural issues and social factors play a major role in the development of hand function in children, as this affects the amount of exposure the children have to different activities and tools which allow them to develop refined fine motor skills (Exner, 1989).

Fine motor skills include reach, grasp, carry, release, in-hand manipulation and bilateral hand use. The descriptions of these skills are discussed below and are a combination of many authors' definitions (Scholtz, 2002; Levitt, 1995; Exner, 1989).

- Reach: Movement and stabilization of the arm and hand for the purpose of contacting an object with the hand.
- Grasp: Attainment of an object with the hand.
- Carry: The movement of the arm in space for the purpose of transporting a hand-held object from one place to another
- Release: The intentional letting go of a hand-held object at a specific time and place.
- In-hand manipulation: The adjustment of an object within the hand after grasp.
- Bilateral hand use: The effective use of two hands together to accomplish an activity.

2.2.2 The development of reach

When a baby is born his arm movements are asymmetrical. He soon begins to take an interest in objects near to him and at approximately two to three months of age starts to watch his own hands, as well as engaging in clasping and unclasping his hands and finger play (Exner, 2001; Sheridan, 1994). After the child becomes visually aware of his surroundings, he then begins to swipe at objects using his arm in a position of shoulder adduction. At approximately three to four months of age, the child develops midline orientation of his hands and they move gradually away from the body as the child holds his hands further away from his body to view them (Erhardt 1994; Exner,1989).

Development of symmetrical bilateral reaching follows at four to five months, which occurs first in supine and then later in sitting positions. The child reaches with his shoulder in abduction and internal rotation, elbow extension, forearm pronation and full finger extension (Erhardt 1994; Exner, 1989). From approximately six months, the child learns to dissociate both sides of the body during movement and unilateral reaching starts to develop. During this reaching phase, the child uses less shoulder internal rotation and abduction and the hand is usually open wider than the actual size of the object (Exner, 2001; Exner, 1989; Sheridan, 1994). As scapular control and trunk stability improve, the child starts to use more shoulder flexion and external rotation with full elbow extension and forearm supination, as well as wrist extension to reach for an object. By nine months, the child starts to use increased trunk extension and slight trunk rotation to reach an object (Sheridan, 1994; Bly 1994; Exner, 1989).

2.2.3. The development of grasp

The tactile-proprioceptive foundation of purposeful grasp is developed through a series of hand reflexes. These reflexes include the traction response, grasp reflex, the avoiding reaction and the instinctive grasp reaction. (Exner, 2001; Sheridan, 1994). As the traction and grasp reflexes decrease, the voluntary ulnar grasp begins to emerge. At six months, the baby begins to hold objects with a palmar grasp, and over time the radial palmar pattern of grasp begins to emerge (Exner, 2001; Erhardt 1994; Exner, 1989).

As the child's physiological forearm flexor tone gradually decreases, he begins to supinate the forearm. At 7 months of age, the child begins to take an object with all the fingers moving into some degree of flexion – this is known as "raking". The child's fisted hand posture develops into one of finger extension, due to the child bearing weight through the upper limb. The child also begins to use more of an open hand during the initiation of grasp (Exner, 1989). At eight to nine months the child begins to take an object between the thumb and two radial fingers (known as the radial digital grasp) and refines the radial palmar pattern. Between 9 to 12 months, the child is able to grasp small objects between the thumb and finger pad (Exner, 2001; Erhardt 1994). Gradually the child begins to achieve inhibition of the third, fourth and fifth digit. This inhibition of the digits in conjunction with increased wrist and metacarpophalangeal stability results in extension of only the index finger and thumb during grasp. By 15 months of age, the child demonstrates a precise pincer grasp (Exner, 2001; Sheridan, 1994; Erhardt, 1994; Exner, 1989). The development of the disc grasp, cylindrical and spherical grasp occur from 18 months and at three years of age the child should be able to perform these grasps with control (Exner, 2001).

2.2.4 The development of voluntary release

In early stages of development, voluntary release of an object from an infant's hand is almost impossible due to the strong grasp reflex and the object needs to be forcibly removed (Erhardt, 1994, Exner 1989). As the child's hand reflexes decrease and there is visual and cognitive development, more volitional release occurs. The transfer of an object from one hand to another starts to begin once the child has started mouthing objects and has gained midline orientation. During the transfer, the object is stabilized by the receiving hand and the hand that is releasing the object is fully opened (Exner, 2001; Sheridan, 1994; Exner, 1989).

At approximately nine months of age, the baby begins to release objects without stabilizing with the other hand. The arm is extended during release and the shoulder control is now also starting to develop during release. As the child masters releasing objects, there is an improvement in elbow control and the child begins to release objects with greater elbow flexion. The arm and hand are in contact with a surface during release

in order to provide stabilization (Exner 2001; Sheridan 1994). At about one year of age, the child masters release with shoulder, elbow and wrist stability, however he does not yet have metacarpophalangeal (MCP) joint control. The stability of the MCP joints and control of the intrinsic muscles during release is refined over the next five years (Exner 2001; Exner 1989).

2.2.5 The development of bilateral hand function

The child has asymmetrical arm movements up until three months of age; thereafter the arm movements become more symmetrical. At approximately 10 months, differentiated arm movements become alternating and reciprocal. This is seen as the child manipulates the object with one hand, while stabilizing it with the other hand (Exner, 2001; Exner 1989). At 17 to 18 months, these arm movements have further developed into simultaneous arm movements, with the child dissociating between the two sides of his body and using both hands simultaneously for different functions (Exner, 2001; Sheridan, 1994; Erhardt, 1994; Exner, 1989).

From 18 to 24 months of age the child begins to develop skills that allow for simultaneous manipulation with both hands. Refinement of bilateral hand skills requires ongoing development of all the other fine hand functions. However, this type of manipulation is only truly demonstrated at two to three years of age (Exner 2001, Sheridan 1994; Erhardt, 1994; Exner 1989). At approximately two and a half years, the mature stage of bilateral hand use begins to emerge, this is described as "the ability to use opposing hand and arm movements for highly differentiated activities such as cutting with scissors" (Exner, 2001, p. 302).

2.2.6 The development of in-hand manipulation

In-hand manipulation skills are responsible for the efficient and effective accomplishment of fine motor tasks. Important motor skills prerequisites for in-hand manipulation are the ability to grasp using the finger surfaces, the use of isolated fingers, the ability to curve and adjust the distal transverse arch of the palm, as well as thumb stability in opposition and abduction. The child also needs to be able to stabilize his wrist in both neutral and extended positions, as well as have the ability to supinate his forearm (Exner, 1989).

Tactile discrimination, perception, sensory integration and cognition are also vital for effective in-hand manipulation (Pehoski, Henderson and Tickle-Degnen, 1997a Case-Smith, 1994; Exner, 1989).

At three years old most children have difficulty rotating an object in their hand and use the surface of the distal and middle phalanx to rotate an object. By five years of age, a child should be able to rotate an object approximately five times in their preferred hand and start to rotate the object more toward the distal phalanx (Pehoski et al, 1997a). A child between the ages of three to six years, should be able to pick up and hold a number of small objects in one hand (Pehoski, Henderson and Tickle-Degenen, 1997b).

2.2.7 The development of carrying

In order for a child to achieve effective carrying of he needs to be able to control small changes in range of movement and be able to co-contract muscles as the carrying tasks demand. During carrying, the child needs to be able to stabilize the forearm, as well as have full control of shoulder rotation patterns (Exner, 1989).

2.2.8 The developmental stages of hand function

Table 1 summarises the normal development of hand function and associates these development milestones with activities that the child should be able to perform. The table has been compiled from the following authors: Scholtz (2002); Levitt (1995); Exner (1989).

2. 3 The development of play

2.3.1 A play system of learning

Play is the primary occupation of children (Morrison and Metzger, 2001) and it is through play that children learn attain various skills (Reilly, 1989; Riddick 1982
Reilly (1989) developed a play system of learning theory. She suggested that outcomes of play are learning to symbolize and learning meanings (Galligan, 2000; Reilly, 1989; Riddick, 1982). She suggested that learning occurs due to the interaction between external facts of reality and internal values. The tendency of symbols to link with values

is the key to the learning process and enables the individual to derive meanings (Reilly, 1989). Imagination is central to symbol formation as symbols require meaning within one's imagination. Symbols translate sensation into meaning or they name and describe aspects of reality and provide a representation of the individual's experiences (Reilly, 1989).

2.3.2 Play development

Play development and behaviour has three hierarchical stages. These stages occur progressively through childhood and are exploratory behaviour, competency behaviour and achievement behaviour. Every one of these stages expresses a higher level of excitement and requires increased functional control. Curiosity is the underlying force that drives play (Primeau and Parham, 1997; Reilly, 1989).

Exploratory play behaviour is seen in early childhood and in new or different events (Riddick 1982, Reilly, 1989). This play is motivated by functional pleasure and curiosity. During exploratory play the child tests reality and explores their environment. This produces foundations for understanding what something is and what the object's function is (Pratt and Allan, 1989; Jeffree, McConkery and Hewson, 1979). Examples of exploratory play are children mouthing and fingering toys and opening and unpacking cupboards (Riddick, 1982).

Compensatory play behaviour is characterized by the need to deal or interact with the environment and the need to be influenced by the environment through feedback mechanisms. The child is constantly changing and monitoring actions to determine how the object can change due to their actions and they tend to repeat activities constantly to achieve a goal. The importance of this stage is persistence which leads to task mastery which develops feelings of self-confidence and self-reliance (Pratt and Allan, 1989; Riddick, 1982).

Achievement play behaviour incorporates the lessons learnt from exploratory and compensatory behaviour. Achievement play behaviour is achievement motivated and guided by a set of expectations that are developed through past experiences of

satisfactions or dissatisfactions. This stage is characterized by competitive behaviour (Primeau and Parham, 1997; Pratt and Allan, 1989; Riddick, 1982).

Play can also be defined by the observable categories of play behaviour (Morrison and Metzger, 2001). These categories are: constructive play which occurs when the child responds to and works with the physical properties of reality and the characteristics of play material (Scholtz, 2002; Jeffree et al, 1979); social play - when children play with other children or adults, (Riddick 1982, Jeffree et al, 1979); imaginative play occurs when a child develops symbols for objects, properties and actions and this play helps with motor planning and organization; pretend play / symbolic play usually start with singular play and then develop into play situations that represent more complex social interactions (Scholtz, 2002) and gross motor play which includes activities such as running and jumping (Riddick, 1982).

The play of the two-year old child is often characterized by extensive exploratory play and gradually becomes more constructive (Riddick, 1982). Three year old children begin to use imaginative play during play activities (Levitt, 1993; Riddick, 1982; Gesell, 1976). Gesell (1976) suggests that the four year old child uses constructive and imaginative play and the five-year old child enjoys creative play and also begins to participate more fully in social play.

2. 4 Learning and motor control in normal development

A child learns through play. His activities and interactions during play constitute a means through which learning and motor control occurs (Knox, 1997). Learning has been defined by Curzon (1980) as "the apparent modification of a person's behaviour through his activities and experiences, so that his knowledge, skills and attitudes, including modes of adjustment, towards his environment are changed, more or less permanently" (Penso, 1987).

It has been suggested that most learning processes are dependent on the ability to move. Once the ability to move has been achieved, then this is applied to learning of activities such as self-care (Levitt, 1995). Children with cerebral palsy often lack this ability to move and therefore their learning experiences in everyday life are diminished. It is therefore important to understand the theories of learning and motor control and how these concepts are used, to enable the therapy given to be effective.

2.4.1 Models of motor control and behaviour

In the past, theorists based explanations of motor behaviour on the hierarchical and reflex models. The reflex model suggested that sensory input would trigger a specific type of motor output and therefore that human movement was completely due to reflex activity (Mathiowetz and Haugan, 1994).

The hierarchical model of control theory originated from the reflex model. It suggested that control of movement originated centrally within the central nervous system and that the assimilation of the sensory input, planning and initiation of movement all originated centrally (Mathiowetz and Haughan, 1994).

The dynamic systems theory has been described as the control over tasks, goals or behaviour, rather than that of the control over muscles and movement patterns (Gulliani, 1991). The dynamic systems motor control theory is a heterarchiacal model. In this model, the central nervous system interacts with multiple systems (personal and environmental) in order to problem solve and complete a task (Mathiowetz and Haughan, 1994).

In the dynamic systems theory model, there are many systems that interact together (Figure 1). One of these systems is the central nervous system. Other systems involved in the dynamic systems model are i) the sensorimotor system – consisting, for example, of perceptual awareness, sensory awareness, regulating systems, postural control; ii) the psychosocial system which includes a person's interests and values; iii) the cognitive system – such as memory and problem-solving skills; and iv) the environment – consisting of the physical, cultural and socio-economic environment. Therefore, motor behaviour can be described as "movement patterns that emerge from the interaction of multiple personal systems and performance contexts to achieve a functional goal" (Mathiowetz and Haughan, 1994). This model also emphasizes the important interaction that occurs between the individual and their environment (Mathiowetz and Haughan, 1994.)

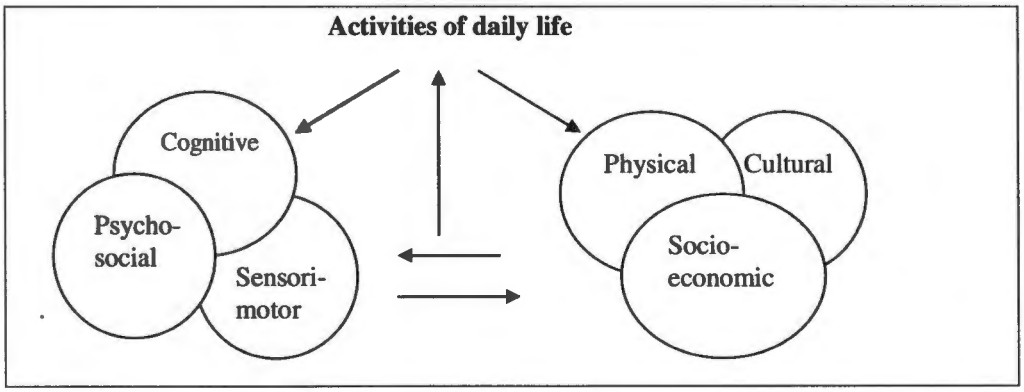


Figure 1: Dynamic Systems Model – adapted from Mathiowetz and Haugen (1994).

2.4.2 Motor Learning

Motor learning has been described as searching for a solution to a task and this solution emerges when the individual interacts with the task at hand as well as their surrounding environment (Case-Smith, 2001). There are two different types of learning – explicit and implicit learning. Explicit learning is when one has a factual knowledge of a subject (e.g. a memory of facts, events and episodes) and this knowledge is directly accessible to conscious recollection. Implicit learning is shown by the person changing skilled movement based on previous performances. Implicit learning is the ability to acquire skill through physical practice without being able to consciously recollect what elements have caused the performance to be improved (Boyd and Weinstein, 2003).

Motor learning is vital in the rehabilitation of children with cerebral palsy. In concept of motor learning is used to aid the children with opportunities to learn new skills and functional tasks (Mayston, 2000). Activities (including those during physiotherapy) need to be converted into meaningful, functional goals for the child. The child needs to be actively involved in the functional task in order to learn a new skill (Mayston, 2000) and repetition and practice of the new skill or task is also vital in order for motor learning and relearning to occur (Goldstein, 2004; Mayston 2000). The mechanisms of motor learning have been discussed further under neural plasticity and the motor learning difficulties that a child with hemiplegia experiences has been discussed in another section of the literature review. The role of motor learning in treatment methods is also discussed later in the literature review.

2.4.3 Neural Plasticity

"Multiple animal studies have shown that that the brain can reorganise patterns of connections to recover from or compensate from injury during development, and this phenomenon of plasticity has been variously attributed to increases in neurogenesis and synaptogenesis or to the reorganization of existing circuitry."

(Vaccarino and Ment, 2006)

Many animal studies have demonstrated that the representations of muscles and movements in the adult primary motor cortex (M1) can undergo plastic changes in response to peripheral or central lesions (Vaccarino and Ment, 2006). Brain plasticity involves the use of other brain pathways to assume the function of the damaged areas of the brain (Goldstein, 2004). Several cellular mechanisms have been implicated to explain the observed plasticity, including unmasking of existing but normally ineffective neural connections, axonal sprouting with synapse formation or a combination of these (Hlustick P, Mayer M, 2006).

It has been shown in recent studies that newly generated hippocampal granule cells have been shown to integrate themselves into pre-existing circuitry, become electrically active and form synaptic connections. In adult strokes, neural stem cells of the postnatal forebrain subventricular zone and the dentate gyrus may give rise to hippocampal pyramidal neurones and striatal neurones and these neurones are then targeted to the injured site. It has also been shown that during recovery from injury in the preterm brain, astrocytes may be able to revert to radial glia, which in turn will generate neurones and thereby generate new cells for brain repair (Vaccarino and Ment, 2006).

In primates with focal motor cortical lesions, intracortical stimulation of the unused cortical territory surrounding the infarct and formerly representing the paralyzed hand now evokes movements of adjacent body parts and similar changes have occur with peripheral and motor nerve lesions. In humans with peripheral nerve injury leading to paralysis, it has been shown, that there is an expansion of the cortical area and the stimulation of which evokes motor potential in unimpaired muscles surrounding the paralyzed ones. Therefore there is evidence of two processes taking place in the reorganizing of the motor cortex. Firstly, the paralyzed body part may still be represented in the motor cortex after long nonuse or secondly, the corticospinal output of the unused coritical territory seems to be redirected to movement control of adjacent body parts (Hlustick P, Mayer M, 2006).

The primary motor cortex (M1) controls the face, arm, trunk and leg. These are located progressively more medially and superiorly along the anterior bank of the sulcus. Studies have shown that after central or peripheral neurologic lesions (ie. after a stroke or arm amputation), reorganization of the primary motor cortex has been demonstrated and

expansion and shifts in motor maps have occurred. This remapping has within the M1 has been suggested as one possible mechanism of motor function recovery after a stroke. (Hlustick P, Mayer M, 2006)

The recent discovery of brain plasticity has provided new evidence that shows the functional anatomy of the brain synapses which are constantly changing in response to alterations in the cell's environment (such as stimulation from the sensory system) and as the a result, the brain is able to acquire new or improved skills through the mechanisms of motor learning (Hlustik and, Mayer, 2006; Goldstein, 2004) There is both nonhuman primate and human evidence that show practice increases rather than decreases the area of the cortex associated with the practiced movement (which has been studied over the time frame of several weeks) and therefore programmed repetition a means of teaching the brain to improve motor performance skills (Goldstein,2004; Muller, 1997)) Motor learning which leads to recruitment of additional M1 areas, even though the M1 is only one on the multiple cerebral areas supposedly involved in motor learning (with the cerebellum being more specifically involved in motor learning). Recruitment of additional M1 units, may be as a result of the newly acquired motor skill using movements segments that are formed by combining neural units of M1 (segmental learning) and this will result in the appearance of new active cortical fields and expansion of the cortical territory corresponding to the practiced muscles/movements (Goldstein, 2004; Muller, 1997). Results from studies have shown that even with a limited amount of practice on a complex novel task can lead to both specific and non-specific improvements in behaviour and to an increase in the size of M1 and primary somatosensory cortex (S1) movement (Hlustick and Mayer, 2006).

Brain lesions acquired at during the prenatal and perinatal period (known as "congenital lesions" cause different types of structural pathologies, depending on the maturational stage of the brain at the time of insult. Injuries that occur during cerebral morphogenesis and neuronal migration, which is in the first and second trimester, most often result in brain malformations. Injuries that occur in the early in third trimester often affect the periventricular white matter (such as periventricular leukomalacia) and injuries that occur later in the third trimester usually affect the grey matter (such as basal ganglia lesions, corticosubcortical infarctions) (Staudt et al, 2004).

When only one hemisphere is affected, the contralateral hemisphere possesses a great compensatory potential. The following theories of sensorimotor reorganization in congenital hemiparesis are: Firstly, when a lesion destroys the normal contralateral corticospinal control over the paretic hand, the contralateral hemisphere develops (or maintains) fast-conducting ipsilateral corticospinal pathways to the paretic hand. Secondly, the reorganization with ipsilateral corticospinal tracts can mediate a useful hand function – however normal hand function only seems possible with preserved crossed corticospinal projections from the contralateral hemisphere. Thirdly, the efficacy of sensorimotor reorganization with ipsilateral cortcicospinal tracts decreases significantly toward the end of pregnancy and patients with late third trimester lesions often no longer achieve any useful hand function despite the availability of such ipsilateral corticospinal tracts. And finally, mirror movements in the paretic hand (during voluntary movements of the nonparetic hand) indicate the prescence of ipsilateral corticospinal projections (Staudt et al, 2004). Mirror movements in children with hemiplegia occur as a result of both the left and right hand motorneuron pools receiving common synaptic input from abnormally branched corticospinal tract fibres whose origin is the undamaged motor cortex – which also indicates an additional form of cortical reorganization (Farmer et al, 1991).

2.5 Cerebral Palsy

2.5.1 Definition of cerebral palsy

Cerebral palsy has been described as a group of disorders of the development of movement and posture, causing activity limitation that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain. The motor disorders of cerebral palsy are often accompanied by disturbances of sensation, cognition, communication, perception, and/or behaviour, and/or by a seizure disorder (International Workshop on Definition and Classification of Cerebral Palsy, United Cerebral Palsy Research, 2004.)

2.5.2 Epidemiology of cerebral palsy

CP affects 2.4 in 1000 children worldwide (Koman, Smith and Shilt, 2004) and more than one million children under the age of 21 in the industrialized world (Taub et al, 2004). Of these children with cerebral palsy, 21 % are classified as having hemiplegia (Rumeu-Rouqette, Grandjean, Cans, du Mazaubrun and Verrier, 1997).

In the Western Cape, there are approximately 2549 children with CP that are currently being managed by the Western Cape Cerebral Palsy Association therapists. These children are mostly from low socio-economic backgrounds. It is unclear how many other children with CP there are in the Western Cape. Of the 2549 children seen from June 2003 to August 2004, 43% were between the ages of two and five years. Fifty-one percent of these children were Xhosa speaking, 25% Afrikaans speaking and 24% English speaking. Sixty percent of these children were male (Western Cape Cerebral Palsy Association, 2003 and 2004).

2.5.3 The classification of cerebral palsy

The definition of CP covers a "large range of clinical presentations and degrees of activity limitation, and it is therefore useful to categorize individuals with CP into classes or groups" (Paneth et al, 2004)

The purposes of classification are: To provide a detailed description of an individual with CP that clearly highlights the nature of the individual's problem and severity; to predict and provide information for others about the current and future health care needs of the individual; to provide sufficient information to permit reasonable comparison of different types of individuals with CP and to provide information that will allow professionals to evaluate the change over time of an individual with CP (Paneth et al, 2004).

Formatted: Bullets and Numbering

Traditional classifications classified children with cerebral palsy via the following distributional patterns: "diplegia" which suggested that the legs were usually more involved than the arms; "quadriplegia" which described a child with all limbs were equally affected; "hemiplegia" which indicated that one side of the body only is affected and "monoplegia" which indicated that only one arm was affected (Bobath and Bobath, 1975). Traditionally the child's type of tone was also added to the classification and included "spasticity" describing velocity dependent resistance of a muscle to stretch, "hypotonia" describing children who are generally very flaccid with decreased muscle tone and excessive joint mobility (Campbell, 1991; Teckin 1989; Bobath and Bobath, 1975), "athetosis" which indicates slow writhing movements of the face and extremities particularly affecting the distal musculature (Teckin, 1989) and "ataxia" which is associated with increased intention tremor and uncoordinated movement. (Campbell, 1991; Teckin 1989).

Contemporary practitioners and researchers however now consider that these traditional classifications and distributions lack insight into the understanding of the individual's condition and management of their condition (Paneth et al, 2004). The new proposed classification, as discussed at the International Workshop on Definition and Classification in 2004, has four dimensions. These four dimensions are as follows:

1. The motor abnormalities of the individual – this indicates the nature and typology of the motor disorder (which include the observed tonal abnormalities that have been assessed and the movement disorders that are present eg. spasticity) and the functional motor abilities of the individual.
2. The level of associated impairments (such as seizures, hearing and visual problems, communication impairments)

3. Anatomical and radiological findings – anatomical findings which indicate the parts of the body affected by the motor impairment, and the radiological findings such as findings on CT or MRI images .
4. Causation and timing - this describes the cause (if clearly identifiable) and when the injury occurred (Paneth et al, 2004).

It is hoped with this proposed new classification, practitioners will more fully address all the issues surrounding Neurodevelopmental dysfunction in individuals with cerebral palsy (Sharpo, 2004) which will enable health care professionals to gain a deeper understanding of the CP individual's levels of abilities and management.

2.5.4 Causes of cerebral palsy

CP may occur as a result of congenital causes, which are associated with foetal development or the birth process. Congenital causes are further subdivided into prenatal causes (where the abnormality arose before the onset of labour) or perinatal causes (where the abnormality arose during or are closely associated with the process of labour.) Acquired cerebral palsy is associated with damage or abnormality after labour until two years of age (Koman et al, 2004; Arens et al, 1978).

The incidence of hemiplegia in children born at full-term with neonatal cerebral infarction has been shown to be less than 25% (Mercuri, Rutherford, Cowan, Pennock, Counsell et al, 1999). It was also shown that the overall involvement of hemispheres, basal ganglia and the internal capsule seemed to be consistently associated with functional outcome (Mercuri et al, 1999). Hemiplegia has been shown to result when there is specific involvement of the posterior limb of the internal capsule that carries the primary motor and sensory tracts. In full-term infants with hemiplegia, the most common lesion is an arterial infarct in the territory of the main branch of the middle cerebral artery or in one of its cortical branches, whereas in preterm infants the most common lesions are periventricular haemorrhagic infarctions (Mercuri,.Barnett, Rutherford, Guzzetta, Haataja et al, 2004).

In South Africa, especially in the Western Cape, Tuberculosis is still rife and is the third highest cause of paediatric mortality in South Africa (Bradshaw, Groenewald, Laubscher, Nannan, Nojilana et al, 2003). Tuberculosis meningitis is one of the leading causes of acquired cerebral palsy in the Western Cape (Krauss-Mars and Lachmann, 1992; Schoeman, 1990, Arens and Molteno, 1989).

2.6 The Underlying Problems of Children with Hemiplegia

"It is important to understand the sequences of abnormal motor development in order to... help plan treatment with a view to preventing abnormality."

(Bobath and Bobath, 1976, 17)

Children with spastic cerebral palsy (therefore including those with hemiplegia) have movement dysfunction as a result of central nervous system lesions. These include neural impairments which include increased or decreased muscle tone, spasticity, the presence of primitive reflexes and reactions and involuntary movements (Goldstein 2004, Carey and Burghardt, 1993; Kluzik et al, 1990; Pratt and Allan, 1989).

Although, muscles and peripheral nerves are not damaged initially, the brain is unable to permit the multitude of coordinated small and large muscle movements, which lead to further muscular and biomechanical non-neural impairments which include shortening and stiffening of joint capsules, ligaments and muscles. These lead to muscle weakness and joint contractures (Carey and Burghardt, 1993). This leads to the children having difficulties when initiating movement and having limited range of movement (Kluzik et al, 1990) These non-neural impairments cause increasing barriers to surrounding environmental and sensory information, as their own bodies create interference (Penso, 1987). Therefore, a child's physical disability can also affect a child's intellectual development because his chances to explore his environment and actively test out situations and try out ideas are limited (Riddick, 1982).

2.6.1 The gross motor development of a child with hemiplegia

Hemiplegia is often recognized earlier than most other types of cerebral palsy due to asymmetry of posture and poor or absent upper limb and lower limb movement. Children are often diagnosed due to their inability to sit and the ability to only use one hand (Yokochi K, Yokochi M and Kodama, 1995; Lanska M, Lanska D, Horwitz and Aram, 1991; Griffiths and Clegg, 1988; Bobath and Bobath 1975).

Bobath and Bobath (1975) state that most children with hemiplegia have the following typical pattern of development: In the early stages of life, when they are lying in supine the affected hand is often fisted, with the baby reaching only with the non-affected hand. Often the hemiplegic arm remains retracted and flexed, or may move into extension as the child turns his face towards that arm (asymmetric tonic neck reflex). The child often has difficulty bringing his hands together. The child usually only rolls to the affected side and is unable to roll to his sound side due to the inability to initiate rolling with his hemiplegic arm and leg (Yokochi et al, 1995; Lanska et al, 1991; Griffiths and Clegg, 1988; Bobath and Bobath 1975).

The child with hemiplegia does not like to be placed in prone, as he needs to support himself on his non-affected arm, but is unable to reach out and play with objects using his affected arm. He does, however, start to creep forward in prone, dragging himself along with the non-affected arm and leg. Sitting is often late, and the children tend to bear most of their weight on their non-affected hip. They have poor sitting balance – often falling towards the hemiplegic side due to poor protective reactions and are not able to support themselves with their affected arm. They often move to sitting from the supine position and use their non-affected arm to push themselves up – causing associated reactions in the hemiplegic arm (Yokochi et al, 1995; Lanska et al, 1991; Griffiths and Clegg, 1988; Bobath and Bobath 1975.). These children also tend to "bottom shuffle"- pulling themselves along on their buttocks with their sound arm and pulling with their sound leg, the hemiplegic leg is dragged along in the process (Bobath and Bobath 1975).

The child with hemiplegia learns to pull himself to standing using only the sound arm. He moves into half kneeling by bringing the affected lower limb up into hip flexion, keeping his sound knee in contact with the floor and his hip extended. He does this as he finds it

difficult to weight bear on the hemiplegic lower limb. As he moves up into standing, he quickly brings his non-affected leg through to bear weight through it. In standing, all the weight is taken through the sound leg and often the affected hip is adducted and retracted. The affected shoulder is also retracted and the elbow is flexed in a flexor mass pattern (Bobath and Bobath 1975).

As the child starts to walk, he bears most of his weight on his sound side, and keeps his affected leg adducted and the knee extended, with his foot in plantar flexion. His affected shoulder is retracted with the elbow flexed and hand fisted. He has poor balance in walking and usually falls over his hemiplegic side. In order to compensate for this, he takes even less weight on his hemiplegic leg. As he starts to walk, he initially lifts up his hip and knee too high when making a step and brings his toes into contact with the floor first, before his heel. This leads to increased spasticity in the ankle, causing increased plantarflexion of the foot when walking. Therefore, in order to bring his heel down, he tends to flex his hip and hyperextend his knee. Over time, due to increasing spasticity, he is unable to place his heel on the floor and therefore his foot remains in plantarflexion with knee flexion. The difficulty and effort of walking causes increased associated reactions (shoulder retraction, with elbow and wrist flexion, and hand fisting) in the child's affected upper limb (Wren, Rethlefsen and Kay, 2005; Fonseca, Holt, Fetters and Saltzman, 2004; Bobath and Bobath, 1975).

2.6.2 Development of reaching in children with hemiplegia

As this study focuses on the upper limb function of children with hemiplegia, a more detailed explanation of the problems associated with functioning of the hemiplegic upper limb is explored.

During the reaching movement of a healthy person, reaching is accompanied by movement in the trunk which assists with balance during the movement, as well as contributing to task completion. The amount of movement in the trunk is influenced by the difficulty of the task at hand and the task constraints. However, in reaching movements of hemiplegics there is a large amount of rotation of the trunk to allow for

greater shoulder displacement during reaching and grasping (Van Thiel and Steenbergen, 2001).

Results show that most healthy subjects make a pointing movement in the following sequence - initial elbow flexion, followed by shoulder flexion and then shoulder horizontal adduction and then finally extending their elbow to move the hand towards the target. There is usually a minimal amount of trunk rotation in this action. However, people with hemiplegia use different movement patterns to reach for the target depending on their level of disability. People with hemiplegia initially flex the elbow, which is then followed by shoulder flexion. Then, instead of using shoulder adduction and elbow extension to reach the target, they move their trunk to bring their hand to the target (Van Thiel and Steenbergen, 2001). It has been suggested that during recovery from a stroke, the nervous system is able to substitute lost elements of the motor pattern (the full range of elbow extension and shoulder adduction) with new elements (the displacement of the trunk) to achieve a task (Van Thiel and Steenbergen, 2001).

Movement fluency can be represented by a movement unit. Movement units (MU) offer a method for quantifying the "amount of smoothness" during a reaching movement (Kluzik et al, 1990). Kluzik et al (1990) defined this movement unit as "the portion of a reach between one acceleration and one deceleration and as the portion of the reach between subsequent points in a curvature-speed relationship." During the maturation of reaching, the first movement unit accounts for an increasing percentage of the total duration of the reach and eventually, as the movement becomes smooth and mature with improved muscle coordination, it will consist of a single MU with only one stop-start action. Therefore, a lower number of movement units reflect greater control of the reaching movement (Kluzik et al, 1990). A measure of hand dysfluency has been described as the number of peaks and valleys in the velocity profile of the hand between the start and end of the hand movement (Van Thiel and Steenbergen, 2001).

A healthy subject has many degrees of freedom of all their joints that they can use during a reaching movement (Van Thiel and Steenbergen, 2001). However, for people with hemiplegia the recruitment and sequencing of different degrees of freedom may be impaired (Van Thiel and Steenbergen, 2001). This leads to impaired fluency of movement and impaired efficiency during reaching, with the period at the end of the

reach being characterized by numerous small accelerations and decelerations. These periods coincide with the hand placement near, but not yet on, the target (Kluzik et al, 1990). In a study by Kluzik et al (1990), subjects with hemiplegia were able to get their hands near the target in one of the first two movement units and then took additional time orientating the hand to touch the target.

The inter-joint (angular) co-ordination between the shoulder and the elbow is segmented and disrupted when the child with hemiplegia points or reaches for an object. They compensate for this by developing new movement patterns (e.g. recruiting new degrees of freedom from various joints). Hemiplegics therefore compensate for the lack of degrees of freedom (for example the lack of degrees of freedom of shoulder movement that will influence the displacement of the hand) via reduced movement fluency (Van Thiel and Steenbergen, 2001). Van Thiel and Steenbergen (2001) showed in their study investigating the reaching, hitting and grasping of eight children with hemiplegia, that fluency of reaching or grasping was not influenced by the target size. Target size did, however, affect the fluency of the upper limb when hitting the target. It was said that during the hitting movement, the smaller the target size the less fluent was the movement. They also suggested that the fluency of the impaired hand was not influenced by the amount of shoulder displacement and suggested that an increase in spatial variability may be a prime characteristic of decreasing fluency in the hand of hemiparetic movements.

It has, however, been shown in children with spastic hemiparesis, that during their involvement in a more functional and challenging activity, there is an increase in the smoothness of movement and a decrease in movement time. This increasing smoothness during a more functional task activity might reflect changes in the degree in which movements are dynamically self-organized and autonomously executed. Therefore, increasing more efficient co-ordination between antagonistic and agonistic muscle groups may lead to fewer movement units (Volman, Wijnroks and Vermeer, 2002).

2.6.3 Development of fine hand function in children with hemiplegia

Most children with hemiplegia have flexor spasticity in their affected upper limb which is often combined with lateral flexion of their neck and trunk side flexion to the affected

side. The upper limb is often in a position of flexion and pronation of the affected arm with retraction of the shoulder and fisting of the hand (Kluzik et al 1990; Bobath and Bobath, 1975). This is often reinforced by associated reactions during the child's efforts to move. It also becomes very difficult to extend the elbow out of its flexed position. The child attempts to use his non-affected upper limb and this often leads to hemi-neglect. Sensory-motor deficits in the upper limb also contribute to this hemi-neglect (Sterr, Freivogel and Schmalohr, 2002 b; Bobath and Bobath, 1975).

It has also been shown that tactile sensibility, pinch strength and manual dexterity are impaired in children with hemiplegia (Gordan and Duff, 1999). In a study comparing 15 children with hemiplegia with 15 children without hemiplegia, it was shown that two point discrimination and spasticity were the strongest individual predictors of static grip force adaptation in children with hemiplegia. From this study, it was suggested that spasticity may limit the ability to finely grade the fingertip force to the object's properties by adding noise to the system, thus reducing the resolution of sensory input or/and motor output. They also suggested that spasticity can alter the precise pattern of muscle activation during grasping and therefore have a direct effect on manual dexterity (Gordan and Duff, 1999).

Due to this spasticity (increased tone) children with hemiplegia have inadequate isolation of movements as they often use total patterns of flexion or extension throughout the upper extremities. They are therefore unable to combine wrist extension with finger flexion and thus are unable to perform differentiated movements with their hands (Gordan and Duff, 1999).

These children also tend to have poorly graded movements leading to impaired co-ordination and accuracy of function, which may be due to spasticity in the affected arm limiting the ability to appropriately grade the fingertip force to an object's properties (Gordan and Duff, 1999). These children lack joint stability in the hand or proximal to the hand (e.g. the child cannot hold the elbow in mid-range flexion and the wrist in neutral during grasping). They also tend to use end of range movements, as they lack the ability to use the middle of the range movement (e.g. with full elbow flexion some children compensate by locking the joint in that position during hand use). Some

problems with grading are typically associated with abnormal tone, muscle weakness, or sensory integrative dysfunction (Exner, 1989).

Children with hemiplegia tend to have inadequate timing of muscle contractions leading to movements that are too fast or too slow for the intended purpose. Instability of joints tends to cause disordered sequence of hand/arm movements (for example, wrist extension may not be initiated until after grasp, instead of during the reaching pattern for the object). Steenbergen, Hulstijn, Lemmens and Meulenbroek (1998) examined the effect of object weight on timing of both time-to-contact phase and time-in-contact phase in children with spastic hemiparesis. They showed that children with hemiparesis had longer time-to-contact phase and time-in-contact phase. The time-to-contact phase was shorter when approaching a heavier object, but the time-in-contact phase was longer with a heavier object – causing an overall increased total movement time. This increase in the time-in-contact phase was shown to be a typical clinical picture of spastic hemiparesis (Gordan and Duff, 1999; Steenbergen et al, 1998). Steenbergen et al (1998) suggested that this might be due to the problems that hemiplegics have whilst controlling distal musculature. The decrease in the time-in-contact phase of the hemiplegic hand might directly imply difficulties in monitoring the sensory signals during the ongoing lift when the weight of an object is not known (Steenbergen et al, 1998). Gordan and Duff (1999) also strengthen this argument by stating that impairments in anticipatory control in hemiplegics are mostly sensory based. It was, however, also emphasized that with practice in reaching and grasping a target, the total movement time decreased. This demonstrated that children with hemiplegia do have the ability to use anticipatory timing and are able to use weight-related information for the control of the manipulation component during grasping (Steenbergen et al, 1998).

Children with hemiplegia have difficulties in bilateral integration of movements. Due to the impairment of a unilateral upper limb, children are unable to effectively bring both hands to midline long enough to accomplish a task. Children with hemiplegia also have disorders of trunk movement and control and therefore need to use one or both upper limbs to support themselves. Trunk side flexion (especially towards the hemiplegic side) will cause the functional range of the arm to be limited and will affect the child's ability to use the arm on the flexed side (Exner, 1989).

All these factors mentioned above, from inadequate isolation of movements to disorders of trunk movement, lead to children using compensatory movements. They develop these compensatory movements to achieve tasks; however these compensations often inhibit the child from developing higher level skills. These factors also lead to impairment of the basic hand functions: reach, grasp, carry and release. Therefore, the emergence of more advanced hand skills (such as in-hand manipulation) will also be impaired (Exner, 1989).

2.6.4 Motor learning for the child with hemiplegia

Children with cerebral palsy often lack the ability to move and therefore their learning experiences in everyday life are diminished. A child with hemiplegia whose hand is fisted will be deprived of tactile stimulation and this will impede the reception of stimuli. This will inhibit the child from fully learning from his experience (Penso, 1987). A child who has an impairment with regard to the reception of one or more modes of stimuli, imperfect perception or imperfect processing of those stimuli or motor incapacity will be disadvantaged in both spontaneous and formal learning situations (Penso, 1987). Penso (1987) provided a learning model for children with impairments (Figure 2).

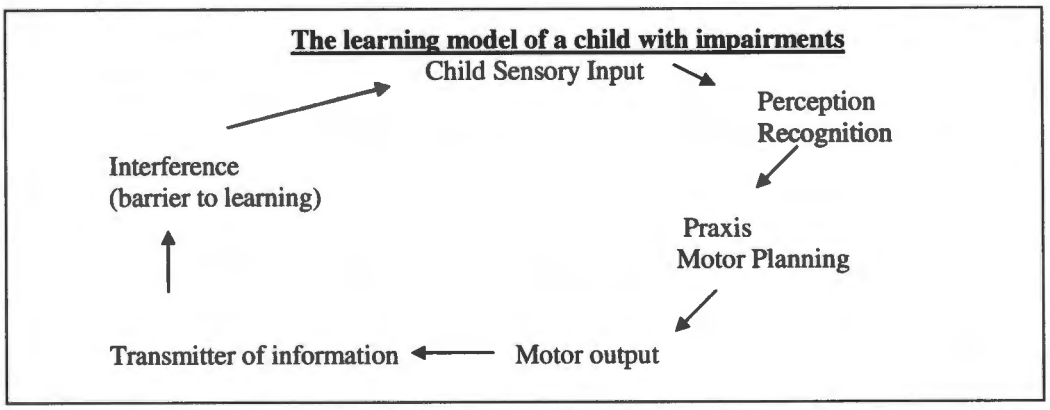


Figure 2: The learning model for children with impairments (Adapted from Penso,1987).

2. 7 Instrumentation

2.7.1 The Peabody Developmental Fine Motor Scale

Use in Research:

There are many different instruments that have been used to assess upper limb function in patients with hemiplegia. The Quality of Upper Extremity Skills Test (QUEST) supplies information relating to movement and postural responses and an evaluation of the quality of upper limb function. The test has four domains: dissociated movement, grasps, protective extension and weight bearing. It provides a total score for the four domains and a mean functional score is calculated for the two limbs combined. The test is validated for children from 18 months to 8 years (Naylor and Bower, 2005). The Assisting Hand Assessment (AHA) is a newly developed and describes the effectiveness with which a child with unilateral disability makes use of their affected hand (assisting hand) in bimanual activities. The AHA is carried out by some observable performance skills revealed through play. The AHA can be used for children from 18 months to 5 years. The Arm Mobility Ability Test (AMAT) assesses deficiencies in activities of daily living. This tool has been tested for validity and reliability in adult stroke patients only and is not appropriate for children (Knopp, Kunkel, Flor, Platz, Rose et al, 1997). The Wolf Motor Function Test and the Motor Activity Log have been used to evaluate the effect of CIMT on adult stroke patients. The former test is used to quantify motor function in stroke and the latter provides information about motor function in life (Taub et al, 1993). However, concerns arise regarding the validity and reliability of these tools (Van der Lee, Beckerman, Lankhorst and Bouter, 2000).

The Paediatric Motor Activity Log (PMAL) and the Toddler Amount of Use Test has been used in one CIMT study to evaluate the function of the upper limb Taub et al (2004). The PMAL was adapted from the adult motor activity log (Taub et al, 2004). These tools have not been tested for reliability and validity in paediatric patients. The Jebson-Taylor Test of Hand Function was used as an assessment tool in one paediatric CIMT study (Karman et al, 2003). At least three studies have used the PDFMS (De Luca et al, 2003; Willis et al, 2002; Crocker et al, 1997) with Willis et al (2002) using the PDFMS to evaluate the efficacy of CIMT in 25 paediatric hemiplegic patients.

The Gross Motor Function Measure assesses the gross motor function of children with cerebral palsy but does not assess fine hand function (Wood and Rosenbaum, 2000; Russel, Rosenbaum, Cadman, Gowland, Hardy et al, 1989). The Bayley Infant Development and Motor Scale is used to assess children between the ages of three and 24 months and has been shown to have concurrent validity with the Peabody Developmental Motor Scale (PDMS) age equivalent scores (Provost et al, 2000). Other childhood developmental tests include the Denver Developmental Scale, which is used only with developmentally delayed children, the Bruininks-Oseretsky Test of Motor Proficiency which evaluates children from the age of 4.5 to 14.5 years and the test of Infant Motor Performance which evaluates children from 32 weeks gestational age to four months of age. The Paediatric Evaluation of Disability and the Functional Independence Measure for children both evaluate self-care, sphincter control and mobility (Flegel and Kolobe, 2002).

It would appear that the fine motor component of the PDMS (PDFMS) is a suitable tool with which to assess the children with hemiplegia. This tool is superior to other described tools which have not been properly validated (Taub et al, 2004), are not applicable to a group of pre-school children (e.g. Bayley Scale), or do not include fine motor assessments (for example the Gross Motor Function Measure). The PDFMS has been used in previous CIMT studies and should therefore allow meaningful comparison between the investigation results.

Description of the Peabody Developmental Motor Scale:

The PDMS was developed by Folio and Fewell (2000). It is a norm-referenced standardized test that is used to assess the gross- and fine- motor development of children between the ages of 0 to 83 months. The test can be used for children with and without disabilities (Hinderer et al, 1989). Folio and Fewell (2000) stated that a purpose of the PDMS is to measure change across time or after intervention for children with motor impairments or delays (Kolobe, Palisano and Stratford, 1998). The tool was also constructed to identify children with delayed motor development, to identify a child's strengths and needs and to identify motor objectives and intervention strategies (Mittal,

Farmer, Al-Atassi, Montpetit, Gervais et al, 2002). The PDMS was then revised, using suggestions from various authors regarding how to improve the scoring of the test to allow it be more clear to the examiners. The updated PDMS was norm-referenced on a sample of 2003 children, including children with physical handicap (Folio and Fewell, 2000).

The PDMS has shown to have test-retest and inter-rater reliability. It was also found to be reliable as indicated by a small standard error of measurement (Hinderer et al, 1989). Gebhard, Ottenbacher and Lane (1994) used the PDFMS to assess 23 children with motor delay and it was shown that the scale had inter-rater reliability.

Content validity was established in the use of the PDMS. Criterion-related validity was also established by determining concurrent and predictive validity. The concurrent validity was established by comparing PDMS scores of children who were delayed with normative scores (Hinderer et al, 1989). Provost et al (2000) examined the concurrent validity of the Bayley Scales of Infant Development and the PDMS. Both scales were administered on 38 two-year old Native American children. It was shown that both scales had concurrent validity for age-equivalent scores of two year olds (Provost et al, 2000). The PDMS was used on a small sample of Xhosa speaking children attending a crèche and the subjects fell within the predicted norms, it was suggested that the PDMS norms were valid for this population of South African children (Hartley-Amien et al, 2005). However, the validity of the PDMS in South Africa is suggested with caution as the study had small sample and has not been published in a peer reviewed journal.

The PDMS consists of a gross motor and a fine motor scale. These two scales may be administered separately or together. Both scores are administered in a 40 – 60 minute time period. There are 170 gross motor items that are divided into 17 age levels. They are also classified into five skill categories. These categories are reflexes, balance, non-locomotor, locomotor and receipt and propulsion of objects. The test allows for a good description of the child's gross and fine motor skills (Hinderer et al, 1989).

The fine motor quotient (FMQ) is a composite of the results of the two subtests that measure the use of the hand muscles. (Folio and Fewell, 2000). These subtests are Grasping and Visual-Motor Integration (VMI). There are 112 fine motor items which are

divided into 16 age categories. These are classified into four skill categories: grasping, hand use, eye-hand co-ordination and manual dexterity.

The PDMS test kit includes a test manual, instructional programming, activity cards, assessment scales and 10 of the 34 testing materials. A description of the PDMS and suggestions for test administration and interpretation of test scores are provided in the manual. Activity cards are included in an effort to bridge the gap between assessment and programming. The activity cards consist of index cards for each gross and fine motor test item, which provide objectives and instructional strategies for each targeted skill (Hinderer et al, 1989).

The starting and end positions are specified for each item, as well as directions for set up and demonstration. Suggestions are provided in the manual for test administration to children with disabilities who cannot be given the standardized version of the PDMS. Basal and ceiling level rules are given in the manual, so the entire PDMS does not have to be administered. Verbal directions may only be repeated once during the testing, second trials are not given to the child unless specified in the manual. For timed items, only one trial is permitted, however, verbal prompting can be repeated once. An item can not be presented to the child again if the examiner feels that the child's optimal performance was not elicited on the first trial. A child must be able to understand simple instructions – as demonstrations are not permitted for items such as placing pegs in a pegboard. However, other authors who have reviewed the PDMS suggest that the child should first receive verbal instruction followed by a demonstration. This allows the examiner to ensure that the item is testing the correct motor behaviour (Hinderer et al, 1989).

The PDMS is scored on a three point scale. The scoring is as follows: "2" indicates a performance that fulfils all the item's criteria; "1" indicates a performance that clearly resembles, but does not meet the criteria and 0 indicates that the child will not or cannot attempt the item (Folio and Fewell, 2000). The three point system is designed to allow partial credit for emerging skills. As infants progress with motor development, items from higher age categories are administered to them. Items that are below their basal level age are not administered and children receive full credit for these items (Kolobe et al, 2000).

The total raw scores from both the fine motor scale and the gross motor scale can be converted into age equivalent and standard scores. These standard scores are called Developmental Motor Quotients (DMQ's). The mean DMQ is 100 and the standard deviation is 15 (Provost et al, 2000). The raw score may also be converted into a scaled score – these are normalized raw scores that are independent of age norms. They are therefore capable of measuring small changes in motor development (Palisano et al, 1995). Items are grouped by age level and identified by a brief title, e.g. "Building Tower". The PDMS manual provides charts which allow the examiner to determine age equivalent and standardized scores. It allows the examiner to calculate various scores – which allows reporting of fine and gross motor function in detail (Hinderer et al, 1989).

As with any other assessment tool, the PDMS has been said to have weaknesses by some authors. These include suggestions that there are limitations when using the gross motor scale to evaluate children with CP (Kolobe et al 1998; Palisano et al 1995). Similarly Palisano suggested that the gross motor scale was not responsive to change in children with cerebral palsy over a six month period (Palisano et al, 1995). Kolobe et al (1998) also suggested that the PDMS gross motor function should not be used in children with hemiplegia/ one sided weakness. This is due to the gross motor function PDMS not scoring left and right sided function – therefore a child will make gains on the PDMS gross motor scale, even if the gains on the affected side are minimal (Kolobe et al, 1998).

However, this observation of Kolobe's does not apply to the fine motor scale as it has been shown to have inter-rater reliability in children with cerebral palsy, including hemiplegia. It has also been used to investigate the hemiplegic hand function of children (Willis et al, 2002) as well as 70 children with spastic cerebral palsy with upper limb and hand involvement (Mittal et al, 2002). Palisano et al (1995) said that neither the fine motor nor gross motor test scores assess the amount of assistance that is needed to undergo certain movements. However, in the PDMS "Guide to Administration" specific instructions are given to the instructor about the cues they must give (Folio and Fewell, 2000).

2.7.2 Kinematic Analysis

The Vicon Clinical Manager (VCM) (Oxford Metrics, Oxford, England) is a six-camera instrument that is used to collect three-dimensional kinematic data, using a sampling frequency of 120 Hz. The Vicon software package (Vicon 370 system, 1992) is used to analyse the data. Reference frames that track limb segment movement are created by surface landmarks placed on the subject. Using this data, joint centre locations and anatomic axes are calculated. The software package then calculates the movement of limb segments about joint axes using mathematical and anatomic modelling. The VCM has been found to be advantageous when assessing children with physical disabilities due to its flexibility and simplicity of use, as well as it being able to detect "clinically useful information" (Song, Concha and Haideri, 2001). The VCM has been used in the kinematic gait analysis of children with cerebral palsy. (Vaughan and O'Malley, 2003; Song et al, 2001; Boyd, Pliatsios, Starr, Wolfe and Graham, 2000).

Other studies have used similar kinematic analysis to investigate reaching in children with cerebral palsy. For example, Van Thiel and Steenbergen (2000); Wu, Trombly, Lin and Degnen-Tickle (2000) and Cirstea and Levin (2000), used the Oprotak 3020, a 3D motion tracking device that records displacements at 200 Hz, to investigate certain aspects of reaching in stroke and hemiplegic patients. Kluzik et al (1990) and Fetters and Kluzik (1996) used the Waterloo Spatial Motion Analysis and Recording Technique (WATSMART) to collect kinematic data whilst investigating the effects of neurodevelopmental therapy on reaching in children with spastic cerebral palsy. The WATSMART was used to capture data from I-red markers placed on the children's arms during a reaching movement. The position of the arm was recorded at a sampling rate of 100 Hz. The digitizer Wacum Intuos A3 has also been used to register movement of cerebral palsy children, with a sampling frequency of 100 Hz (Volman et al, 2002).

The calculation of the number of peaks and valleys (movement units) in the tangential velocity profile between the start and the end of a movement helps to determine the smoothness or fluency of the reaching movement (Fallang et al, 2003; Van Thiel and Steenbergen, 2001; Cirstea and Levin 2000; Wu et al, 2000; Kluzik et al, 1990). All of these authors (apart from Kluzik (1990) who used a movement unit diagram of acceleration versus time) used tangential velocity profiles (velocity versus time) to assess

movement smoothness. These authors measured the number of peaks and valleys in the velocity or acceleration to determine the number of movement units in the reaching motion. A movement unit is defined as one acceleration and one deceleration. However, authors differ in the minimum rate of change that is needed to quantify an acceleration or a deceleration ranging from 5mm/sec (Kluzik et al, 1990) to 20 mm/sec (Fallang et al 2003). The research presented in this thesis used 20 mm/sec to indicate a change in acceleration or deceleration, as this was most widely used in other studies (Fallang et al, 2003; Van Thiel and Steenbergen, 2001; Cirstea and Levin 2000) when investigating the kinematics of reaching and would therefore allow for comparison with other research projects if indicated.

Authors have also investigated the peak velocities during the reaching movement, as well as calculating the length of the initial movement unit to determine if improvement in the reach has occurred (Fallang et al, 2003; Wu et al, 2000, Cirstea and Levin, 2000).

The start of a reaching movement was described by Van Thiel and Steenbergen (2001, p168) as being "determined by finding the moment prior to the moment of peak tangential velocity at which the hand reached 10% of the peak velocity." They also described the end of the movement as being when the hand reaches the target, excluding the grasping phase. In contrast, Kluzik et al (1990) and Fallang et al (2003) describe movement time simply as being the period of time between the visible initiation of movement and when the hand touches the target (the end of the movement).

Research has also investigated the range of movement (degrees of freedom) in the trunk and the elbow. This has been well described by Cirstea and Levin (2000) and has been discussed in greater detail previously in this chapter. I-red markers were placed on the following points on the child, in order to measure the degrees of freedom: the wrist (head of the ulna), the elbow (lateral epicondlye), the shoulders (ipsilateral and contralateral acromions) and the trunk (top of the sternum). This placement has been duplicated in this research study.

Authors disagree as to the optimal direction of the reaching movement required to obtain the best functional evidence when collecting kinematic data. Cirstea and Levin (2000) sat children with hemiplegia in an adjustable chair at an adjustable table. Their feet were

placed firmly on the floor. The children were not strapped into the chair in order to allow for freedom of movement of the trunk. The child's hemiplegic hand was placed on a box on the ipsilateral side, alongside the child's hip. The height of the box was the same height as the patient's hip and 10 cm lateral to the hip. The child was asked to move the hand from this position and reach diagonally across his body to touch a target on the opposite side of the table (on his non-affected side). This movement involved the "coordination of multiple joints and represented a movement that ought to be required during recovery of a stroke" (Cirstea and Levin, 2000).

2.8 Neurodevelopmental Therapy for the Child with hemiplegia

2.8.1 Different types of management in upper limb dysfunction

There are many methods of therapy that can be used to treat upper limb dysfunction. Boyd, Morris and Graham (2001) mention a large number of modalities from behavioural and environmental treatments to pharmacological agents and surgery.

The behavioural and environmental treatments consist of physiotherapy, occupational therapy, NDT, conductive education, strength training and CIMT (Boyd et al, 2001). In order for the above treatment methods to be effective, motor learning needs to occur to allow the patient to obtain new or improved skills (Hlustick and Mayer 2006, Goldstein 2004). Boyd et al (2001) conducted a systematic review of the literature relating to management of upper limb dysfunction published prior to December 2000. For inclusion, studies needed to be either randomised or non-randomised controlled trials, and all trials needed to have an objective outcome measure. Forty-six prospective non-randomised trials were identified (all using an objective outcome), of which only five were randomised, controlled clinical trials. Of the five randomised trials that were found, two trials investigated the use of Botulinum Toxin A in people with hemiplegia, one investigated the use of isometric exercises and the other two investigated the use of inhibitory casting versus NDT (these studies on inhibitory casting are discussed in greater detail below). The review concludes that there is a paucity of randomised clinical trials investigating management of upper limb dysfunction.

It is beyond the scope of this literature review to describe all the modes of therapy that are available for the child with hemiplegia. The theories and research-based information related to NDT and CIMT will be fully discussed.

2.8.2 A Background to the Bobath and NDT concept

"...A whole new way of thinking, observing, interpreting what the patient is doing, then adjusting what we do in the way of techniques – to see and feel what is necessary, possible for them to achieve. We do not teach movements, we make them possible..."

(Bobath, 1981 from Margaret Mayston, 2000)

The Bobath concept was initiated by Karl Bobath and Berta Bobath, a neuropsychiatrist and a physiotherapist, in the mid 1940's. The Bobath approach has developed substantily over the years and is widley known as Neurodevelopmental therapy - NDT (Butler and Darrah, 2001a). It was based on Berta Bobath's observations of people with abnormal movement patterns and neuroscience theories at that time. The Bobaths initially based their concept on reflex and hierarchical models of motor control (Butler and Darrah, 2001b) and they believed that the motor problems of cerebral palsy were due to the dysfunction of the central nervous system and this interfered with normal motor development and skills. Therefore, their approach focused on components that would have been affected by damage to the central nervous system and included sensorimotor components such as muscle tone, reflexes and abnormal movement patterns. The goals of Bobath therapy were to aid normal motor development and function, as well as to prevent deformities and contractures (Butler and Darrah, 2001a). The Bobaths developed a treatment that used handling techniques to inhibit spasticity, abnormal reflexes and abnormal movement patterns and also used "reflex-inhibiting postures".

As neuroscience progressed, the Bobath's changed their approach from reflex-inhibiting postures and started to use the concept of "key points of control" in which the therapist inhibited abnormal movements while the child was moving and facilitated more normal movement patterns. (Butter and Darrah, 2001a). The underlying reasoning for this was to allow the child to carry over the new movement patterns into everyday function. Over time, the Bobaths realized that it was necessary for a child to take over the control of

their own movement and changed their practice from one incorporating postural reflexes, to include postural reactions – such as balance (Butter and Darrah, 2001a; Camissa, Calabrese, Myers, Tupper, Moser et al, 1995). Later still, the Bobaths realized that Bobath treatment was not having a carryover into the child's activities of daily life. Therefore, specific functional tasks in the child's home and school settings were encouraged therefore encourage the carryover of the this treatment in activities of daily life (Butler and Darrah, 2001a).

2.8.3 The NDT concept

Margaret Mayston (2000) summarizes the Bobath Concept as the following, "It is primarily a way of observing, analyzing and interpreting task performance. This also includes the assessment of the client's potential, which was considered to be that task or those activities which could be performed by the person with a little help, and therefore possible for that person to achieve independently where possible... and involves the use of various techniques."

The NDT concept should not be seen as a treatment technique, but rather as an approach to assess and assist children with cerebral palsy in performing functional tasks and to enable these children to improve their function (Sharkey, 2002; Barry, 1996; De Gangi, 1994). NDT is an individualized treatment that has also been described as "a method of assessing diverse, neurologically impaired children, identifying their functional state and needs, planning and ... treating the child to facilitate meeting those needs" (Sharkey, 2002, p430).

The NDT treatment and concept is based on a thorough assessment of the child which should determine the specific problem areas that the child may have that may be inhibiting his function. During the NDT treatment, the therapist controls or guides the child's motor output to her sensory input (through play and handling), but then has to withdraw her help gradually and systematically so that the child begins to control the movements without assistance (Bly, 1991). These activities need to be converted into functional goals which are realistic according the child's potential. The child needs to be actively involved in the participation of the functional task, and given the opportunity to

practise the task in order for motor learning to occur and to allow the child to gain new or improved skills (Mayston, 2000) Recently, functional activities have been emphasized as essential components of NDT in to translate tasks into functional activities to facilitate motor learning (Camissa, Calabrese, Myers, Tupper, Moser et al, 1995; Bly, 1991).

There have been changes in the Bobath approach over the years and some of the approaches have been questioned and are being investigated and changed. Some of the changes in approach have been regarding the influence of tone inhibition, muscle weakness, normal movement patterns leading to function and the avoidance/non-avoidance of compensatory strategies (Mayston, 2000). The term "inhibition" was used by Bobath as a physiological explanation for the effect of handling on spasticity. However, this term is incorrect as during treatment therapists not only cause a change in inhibitory and excitatory synapses, they also affect the visco-elastic properties of the muscle. It is also felt that for any lasting effect of spasticity to be obtained, the patient needs to perform more efficient functional tasks.

The Bobaths felt that muscle weakness was secondary to the problems of abnormal tone; however it has shown that children with cerebral palsy find it difficult to generate voluntary muscle activity and therefore have muscle weakness, which further inhibits their function. It was proposed that facilitating normal movement patterns would lead to improved function, however it is not realized that movement patterns will not automatically lead to function and function must be practiced in the correct context and the child needs to practice functional, meaningful tasks for therapy to be effective (Mayton, 2000). There is also ongoing debate about the amount of compensation that a patient is allowed to use – the Bobaths initially restricted compensatory strategies, however, it is now under discussion that a patient should be encouraged to reach their maximum functional within the limits of their damaged central nervous system and this might incorporate some compensatory strategies (Mayston, 2000).

2.8.4 Efficacy of NDT

In general there has been a lack of randomised controlled trials investigating the effectiveness of neurodevelopmental therapy (Boyd et al 2001; Butler and Darrah, 2001;

Ottenbacher and Jannell, 1993; Ernst 1990). Most studies investigating the efficacy of NDT have been limited by small sample sizes, heterogeneity of the sample group, variability in response to treatment and a possible lack of sensitivity of the outcome measures (Brown and Burns, 2001; Boyd et al, 2001; Butler and Darrah, 2001).

Brown and Burns (2001) conducted a systemic review to evaluate the efficacy of Neurodevelopmental Treatment in paediatrics. Of the 147 published articles that were reviewed, 17 articles were felt to adequately met the study criteria. The criteria for the study were: the use of NDT as a treatment; the subject group consisted of children from birth to 18 years with some neurological dysfunction; a clinical outcome was used in the study; the subjects were randomized into assigned treatment and control groups and the study was published after 1975. From this review, only 7 of the 17 studies reported a benefit from using the NDT approach. Of the eleven studies that investigated the use of NDT in children with cerebral palsy only 6 studies reported benefits of using NDT. When looking at the use of NDT with high-risk/low weight infants (6 studies), only one study supported the use of NDT whereas the other five studies did not.

Butler and Darrah (2001) conducted an extensive review of the literature published prior to April 2001. Only 21 studies met the criteria of being NDT based and dealing with CP. Six of these studies were randomised controlled trials. The largest number of subjects in any study was 50 children with CP (Law, Russel, Pollock, Rosenbaum, Walter and King G, 1997). Two of these studies dealt with kinematic analysis of the upper limb. Only two studies had undergone a power calculation to determine the required sample size. Butler and Darrah (2001, p789) stated in conclusion to this literature review that "with the exception of immediate improvement in dynamic range of motion, there was not consistent evidence that NDT changed abnormal motoric responses, slowed down or prevented contractures, or that it facilitated more normal motor development or functional motor activities". These comments were criticized by the NDT association who stated that absence of published evidence regarding NDT effectiveness could not be construed as proof that it is ineffective (Sharkey, 2002). It was also felt that just because a study did not show any significant difference or improvement in the population sample; it does not mean that the treatment was clinically insignificant.

A number of studies have been conducted to determine the effectiveness of NDT; however, some of these did not compare NDT to any other type of therapy (Knox and Evans, 2002; Bower, McLellan, Arney and Campbell M, 1996; De Gangi 1994; Bower and McLellan 1992; Kluzik et al 1990). Some of these studies did, however, show that an intense course of therapy (an hour of therapy everyday) was more effective than conventional therapy (one hour of therapy every two weeks) – which is not surprising. Interestingly, however, it was also noted that there was a maintenance in the improvement of function after an intensive, more frequent, course of therapy (Knox and Evans, 2002; Bower et al, 1996; Bower and McLellan, 1992). It has also been emphasized that the task content that is used in an activity affects the functional improvement of the child (Volman, Wijnroks and Vemeer, 2002).

Intense NDT has been compared to the practicing of reaching in children with cerebral palsy over five days. There was no significance difference in each of the groups after the five days, perhaps due to the small sample size (n=5) However, when both groups were combined a general improvement in some of the variables were seen (Fetters and Kluzik, 1996).

Conventional NDT (approximately once weekly for 45 minutes) versus inhibitory casting with intensive NDT (twice-weekly therapy for 45 minutes and wearing cast for 4 hours daily) has also been investigated. Inhibitory casting is not CIMT. It is a procedure where a cast is placed on the child's hemiplegic arm to maintain specific joint range in a functional position, as well as to attempt to decrease tone and increase the functional effects of the child's movement. This research demonstrated that intense NDT therapy plus casting was more effective than a regular therapy programme for children. This study was limited by the absence of a group receiving intensive NDT without the inhibitive cast (Law et al 1997; Law, Cadman, Rosenbaum, Walter, Russel and DeMatteo, 1991).

2.8.5 Summary of NDT

In conclusion, NDT therapy is anecdotally clinically effective. More research needs to be conducted to prove this scientifically. Specific limitations of available studies include

small sample sizes, a lack of appropriate control groups; and few studies have compared NDT to other therapeutic interventions.

2. 9 Constraint-induced Movement Therapy

2.9.1 The theoretical foundation of CIMT

It has been suggested that restraining the unaffected arm of a patient with hemiplegia may facilitate functional recovery by increasing the use of the affected limb (Willis et al, 2002; Sterr, Elbert, Berthold, Kobel, Rockstroh and Taub, 2002a; Taub, Uswatte and Pidikiti, 1999). CIMT is a rehabilitation treatment for hemiplegic patients that restricts the use of the less-affected upper limb thereby forcing the patient to use his affected upper limb. The less-affected upper limb may be restrained using a variety of devices (Taub et al, 1999).

The first report of CIMT was published by Ogden and Franz (1917, in Dromerick, Edwards and Hahn, 2003) and in their study primates with pyramidal tract lesions were constrained. Taub et al (1999) subsequently began investigating the use of CIMT in primates. One forelimb of the primate was deafferentiated to simulate hemiplegia. The restraint of the non-affected limb of the primate led to the improved use of the affected upper limb (Taub et al, 1999).

Through these primate studies, the "learned non-use" theory was developed. This theory is based on the behavioural mechanism that occurs when a primate or person attempts to use a paretic limb. The attempts are often painful and frustrating, causing decrease in function e.g. dropping food when eating. The person or primate learns to use the three other unaffected limbs to compensate for lack of function in the affected arm. This serves to positively reinforce the non-use of the affected limb (Sterr, Freivogel and Schmalohr, 2002b; Taub, et al 1999). Subsequent to the animal studies, CIMT was investigated in human trials, using adults who had experienced cerebrovascular accidents (Taub and Uswatte, 2003).

CIMT is thought to facilitate motor learning and induce cortical reorganization in patients after a stroke (Liepert, Bouder, Miltner, Taub and Weiller, 2000). Liepert et al (2000) studied 13 stroke patients and with the use of focal transcranial magnetic stimulation mapped the cortical motor output area of the abductor pollicis muscle of the more- and less-affected hands. The subjects participated in CIMT therapy for 12 days, wearing the restraint for 90% of waking hours and having six hours per day of shaping (which is discussed below) over the eight weekdays. After the 12 days, the mapped area of abductor pollicis of the affected hand was significantly increased. However, this study was limited by the small sample size and the fact that the control group underwent a different physiotherapy regimen, making comparison between the groups less meaningful.

CIMT therapy is based on three principles:

- Restraining the non-affected hand and thus forcing the use of the affected hand. Taub et al (1999) stated that the person should attempt to use their more-affected upper limb through restraining the more affected limb, for a total of 90 % of waking hours.
- Intensive training of the affected hand, known as "shaping". "Shaping" is a technique which encourages patients to repeatedly use the paretic arm for many hours a day for consecutive days (Miltner, Wolfgang, Monika, Dettmers and Taub, 1999). Traditional shaping therapy is also described by Taub et al (1999) as repetitive training of the more-affected limb for six hours a day, interspersed with a one hour rest period, on weekdays for two-or-three weeks. This therapy is also performed on a one-on-one basis i.e. one therapist treating one patient at a time (Taub, 2000).
- Maintaining the non-affected hand with a restraint and training of the affected hand for a period of time (Sterr et al, 2002a; Taub et al, 1999; Miltner et al, 1999). This period of time ranges from two weeks (Levy, Nicholas, Schmalbrock, Keller and Chakeres, 2001; Miltner et al 1999; Kunkel, Knopp, Muller, Villringer, Villringer, Taub and Flor, 1999) to three weeks (Willis et al, 2002).

2.9.2 Adult CIMT studies

Results of CIMT studies undertaken in humans over the past ten years have appeared positive (Page, Sisto, Levine and McGarth, 2004; Bonifer and Anderson, 2003; Sterr et al, 2002a; Sterr et al, 2002b; Levy et al, 2002: Liepert et al, 2000; Dromerick, 2000; Kunkel et al, 1999; Van der Lee, Wagenaar, Lankhorst, Vagelaar, Deville and Bouter, 1999; Miltner et al, 1999; Taub, Miller, Novack, Cook, Flemming et al, 1993). Many of these studies are limited by small sample sizes and the study designs are not all scientifically rigorous (Table 2). It is also important to note that all these studies have been conducted in First World countries.

Table 1: Summarizing non-modified adult CIMT studies

Authors	**Kunkel et al, 1999**	**Levy, et al. 2001**	**Van der Lee, 1999**	**Miltner et al. 1999**	**Bonifer et al 2003**	**Dromerick et al. 2000**	**Taub et al, 1993**	**Liepert et al, 2000**	**Liepert et al, 1998**
Sample Size and Age range	N=5 47-66yrs	N= 2 48, 49yrs	N=66 18-80yrs	N=15 33-73yrs	N=1 53 yrs	N=20 61-82 yrs	N=9 65 yr(m)	N=13 33-73 yrs	N=6 52 yrs (m)
Method of CIMT	**	**	**	##	$$	**	**	##	##
Type of CIMT	AS & RHS	Mitt	AS & RHS	AS & RHS	AS & mitt	Mitt	AS & RHS	AS & RHS	AS & RHS
Matched Control Group	N	N	Y	N	N	Y	N	N	N
Randomised	N	N	Y	N	N	N	Y	N	N
Outcome (p <0.05)	+	0	0	+	0	+	+	+	+

** - indicating CIMT everyday for two weeks, 90% of waking hours and shaping therapy six hours a day every weekday for two weeks.
- indicating CIMT everyday for 12 days, 90% of waking hours and shaping therapy for six hours per day for 8 days.
$$ - indicating CIMT everyday for three weeks, 84% of waking hrs and shaping therapy six hours a day over weekdays for three weeks.
AS – arm sling
RHS – resting hand splint
m - mean
Outcome related to CIMT - +: Significant improvement in outcome of CIMT group
0: No significant change (either just for CIMT group or between CIMT and control group)
- : Deterioration in CIMT group

2.9.2.1 Adult randomised controlled trials

There are very few randomised controlled trials investigating the effectiveness of CIMT and there is a definite need for more such studies to prove the efficacy of this therapy. Specifically, an active motor treatment is required as a control treatment to evaluate whether CIMT is superior to other available treatments (Dromerick, 2003). There is also a need for a large-scale randomised controlled trial to compare a CIMT protocol with equally intensive physiotherapy (Siegert and Lord, 2004).

There are only two randomised controlled trials in adults that have been published regarding CIMT. Dromerick et al (2000) studied 20 patients, randomly assigned to two groups. The CIMT group wore a padded mitten for six hours per day for 14 days, as well as treatment with standardised occupational therapy for two hours per day, five days a week for the 14 days. The control group received identical occupational therapy treatment for the same period of time, without wearing the mitt. The CIMT group showed significantly greater improvements in upper limb strength, dexterity and co-ordination compared to that of the control group. There was no significant difference between the two groups in eating, grooming, bathing or lower limb dressing on the Action Research Arm Test (scores the patient on the quality of the movement of the upper limb), however the CIMT group performed significantly better in upper limb dressing and grooming.

Van der Lee et al (1999) studied 66 chronic stroke patients who were randomly assigned into two groups – a CIMT group and NDT treatment group. The CIMT group received the same treatment as mentioned in the first study. Both groups improved following their respective treatments, but there was no significant difference shown between the quality of upper limb movements in the CIMT group and the NDT treatment group. Taub (2000) criticized this study for not using individualized therapy, identifying this as a possible reason for lack of a difference between the CIMT and NDT groups.

It is of interest that the largest and best designed randomised controlled trial investigating CIMT was not able to objectively determine any benefit of using CIMT compared to a well-matched control (Van der Lee et al, 1999).

CIMT is an intensive, time-consuming rehabilitation programme. It consists of three components, as mentioned earlier in this chapter: restraining the upper limb, intensive practice of the affected upper limb ("massed practice") and encouraging use of the affected upper limb through shaping. A great number of resources and a large amount of patient input, as well as staff requirements are necessary to implement CIMT and questions have been raised as to whether all these components are necessary (Page et al, 2004; Siegert and Lord, 2004; Sterr et al, 2002a). Issues have also been raised about the length of the shaping therapy, as most stroke patients are weak and six hours a day of therapy is likely to result in fatigue, potentially negatively impacting on the treatment (Sterr et al, 2002a).

A few studies have, therefore, investigated the effectiveness of using modified CIMT. Page et al (2004) studied 17 patients to investigate the use of modified CIMT. One group of patients had their unaffected upper limb restrained for a total of 10 weeks (five hours per day for five days a week) with therapy sessions three times per week for 30 minutes per session. This group of patients was compared with a group who received therapy alone and another group who obtained no therapy. The results showed an improvement in the CIMT patients' upper limb function. Modified CIMT was not compared to intensive CIMT and therefore no conclusions can be made as to whether one is more beneficial than the other.

Sterr et al (2002a) used 15 subjects to investigate the use of three hours per day compared to six hours per day of shaping therapy. The results showed that six hours a day of therapy was more effective, however the group who underwent three hours of therapy also showed a significant improvement in function.

2.9.3 Paediatric CIMT studies

Ten research papers have been published regarding the use of CIMT in children (Naylor and Bower, 2005; Eliasson et al, 2005; Taub et al, 2004; De Luca et al, 2003; Karman, Maryles, Baker, Simpser and Berger-Gross P, 2003; Glover, Mateer, Yoell and Speed, 2002; Willis et al 2002; Pierce, Daly, Gallagher, Gershkoff and Schaumberg, 2002; Charles, Lavinder and Gordan, 2001; Crocker, Mackay-Lyons and McDonnell, 1997). Of these studies, five are case reports discussing between one and three children only (De Luca et al, 2003; Glover et al, 2002; Pierce et al 2002, Charles et al, 2001; Crocker et al, 1997). Eliasson et al (2005), Taub et al (2004) and Willis et al (2001) conducted controlled trials with patient samples of 41, 25 and 22 children respectively. Naylor (2005) investigated the use of CIMT in 9 children and used the children as their own controls in a cross-over study design. Karman et al (2003) investigated the use of CIMT in seven children with hemiplegia as a result of acquired brain injury.

2.9.3.1. Paediatric case studies and case series

Crocker et al (1997) published a case study describing the effectiveness of CIMT in two children with hemiplegia. The two subjects were a two-year old girl with right-sided hemiplegia and a three-year old boy with left-sided hemiplegia. The two children's affected upper limbs were fitted with resting splints which ranged from the upper third of the forearm to two centimetres distal to the fingertips. The parents of the children were instructed that their children must wear the splint during waking hours for three weeks. The authors stated that they aimed for eight hours of forced use a day but there was no mention whether this was accomplished and how much hands-on therapy they received over the period. The parents of the girl reported that she "enjoyed wearing the splint" and wore it for at least 10 hours a day, however the boy "grew irritated, withdrew from play activities and often removed the splint." The boy was therefore removed from the study. The girl was assessed using the Peabody Developmental Fine Motor Scale (PDFMS) and was shown to have improved in her upper limb function.

Another case study by Pierce et al (2002) also showed improvement with the use of CIMT. This CIMT protocol consisted of wearing the restraint "as much as possible" at home, as well as

wearing the mitt during two one-hour sessions of physiotherapy, and two one-hour sessions of occupational therapy for three weeks.

Charles et al (2001) investigated the use of CIMT on three boys with hemiplegia aged 8, 11 and 13 years old respectively. These children had their non-affected upper limbs constrained with a cotton sling for six hours a day for 14 consecutive days and during these six hours the children received "continuous therapy" in their respective homes. At the end of the two weeks, all three boys showed improvement in the Jebson Hand Function test. Subject one and two both showed an improvement in the total movement time, two-point discrimination and tactile discrimination, and both had reorganization of the grip-lift synergy post treatment. Subject three, however, showed an increase in the total movement time and showed little improvement in the grip force synergy; however he did improve in tactile discrimination.

A 15- month girl with spastic quadriplegia had her more unaffected upper limb placed in a bivalved fibreglass cast from the shoulder to the fingertips with the elbow in 90 degrees flexion and the wrist in neutral. The cast was applied for 3 weeks during which time she received 15 days of six hours a day therapy in her own home. The authors reported an improvement in her Peabody Fine Motor Scale (PDFMS) scores and in the Paediatric Motor Activity Log (De Luca et al, 2003). The Paediatric Motor Activity Log, although used by some to evaluate CIMT (Taub et al, 1999), has not been properly validated (Van der Lee et al. 1999).

Glover et al (2002) investigated the use of CIMT on two children aged 19 months and 38 months respectively. The 19- month old child wore a forearm splint on his unaffected limb during waking hours for 11 days. On nine of these days, he also received therapy - however, no mention was made of the duration of the therapy sessions. The author stated that the child showed a functional improvement after the 11 days, but no standardized test was used when assessing his function. The other child, who was casted with Plaster of Paris for a fracture of the unaffected arm, also improved in function.

Karman et al (2003) investigated the use of CIMT in a case series of seven children who were admitted to a hospital traumatic brain injury unit. Six of these children were admitted for

subacute rehabilitation and the other child was readmitted for the purposes of undergoing CIMT. The inclusion criteria in the study were diagnosis of hemiplegia, the ability to follow instructions and to attend to a task for at least three minutes. The children were assessed using the Actual Amount of Use Test (AAUT) before starting and directly after the intervention. The treatment consisted of the children wearing a mitt during waking hours on the less-impaired hand and therapy "shaping" for six hours every weekday. It is important to note that during some of these shaping therapy sessions, a trained therapist was not available and other staff and parents were asked to supervise the children in activities. It is unclear whether these people adhered to the structured protocol or not. After two weeks, the children were reassessed and all seven children improved in their AAUT and in quality of movement scores.

2.9.3.2. Cross-over design

Naylor (2005) investigated the use of CIMT in nine children who were used as their own controls. The children initially had four weeks of "regular hand therapy" which consisted of the children receiving one hour of bimanual hand activities fortnightly. Thereafter, the children underwent one hour a day of CIMT therapy for four weeks (two days a week by therapist and other days by the parent or caregiver). The children were not restrained using a mitt, but were encouraged to use their hemiplegic hand. The children were assessed thereafter at two months, four months and again at six months using the QUEST (Quality of Upper Extremity Skills Test). The researchers found that the children demonstrated greater improvement during the CIMT treatment phase. However, these results can not be attributed only to the encouragement of using the hemiplegic hand, but may also be due to the increased amount of time that the children spent during their CIMT intervention compared with that of the regular therapy.

2.9.3.3. Randomised controlled trials

Eliasson et al (2005) investigated the use of CIMT on 21 patients compared to 20 control subjects between the ages of 18 months and four years. The Assisting Hand Assessment was used to measure hand function. The CIMT intervention was modified with the child being requested to wear the CIMT mitt for two hours per day for seven days a week over two months. The intervention took place in the child's own environment (for example pre-school or at home)

and the caregiver of the child had the responsibility of ensuring the child's compliance with regard to wearing the restraint. The treatment programme was based on children being given tasks that involved motivating the child to use their hemiplegic hand and repetition of movement. The control group's intervention is unclear, but appears to have consisted of children receiving physiotherapy approximately twice a month. The CIMT group attended the same number of physiotherapy sessions, as well as their intense therapy. The children were assessed after two months and then at six months. Results showed that the CIMT group improved more than the physiotherapy group, but no mention was made whether this was significant or not. However, the improvement in the study group cannot be attributed to the restraint alone as the CIMT group had a great deal more therapy than that of the control group.

Willis et al (2002) investigated the use of CIMT in 25 children with hemiparesis between the ages of one and eight years. The children were randomised into a treatment and control group. All the children were assessed using the PDFMS. The researchers were not blinded to group allocation. The treatment group had a plaster cast placed on their unaffected upper limb for a month and the control group received "no additional intervention." Both groups continued their routine visits to therapy. It is a cause of concern that the only time the cast was examined was for repairs. It was mentioned in the study that several of the parents withdrew their children from the study and had their casts removed due to "their children's irritability and/or complaints about wearing the cast."

After one month, the cast was removed from the treatment group and both groups were reassessed. Six months later seven of the twelve CIMT group patients and ten of the 13 control group patients returned for follow up assessment. The children who were previously in the control group were then allocated with the cast and vice versa. They were then reassessed after another month using the PDFMS. Their results showed no significance difference between the PDFMS scores of the treatment and control group, even though the treatment group did acquire more points on the PDFMS after one month of casting. Subjectively, parents felt that their children had improved by using CIMT.

Taub et al (2004) also investigated the use of CIMT on 18 children. The age group of these children ranged from seven months to eight years, a very wide age range for a small sample group. The children were recruited from the local area early-intervention programmes and health care practitioners. The children were randomly assigned to a treatment or control group. The CIMT (treatment group) comprised nine children who had their less-impaired upper extremity casted from the upper arm to the fingertips by a lightweight fibreglass cast. The skin was checked weekly. These children wore the cast for 21 days, and also had six hours of therapy every day. The control group consisted of nine children who only received therapy for a mean of 2.2 hours per week. This study is clearly limited by the fact that the control group and CIMT group were not equally matched with the CIMT group receiving much more intensive physiotherapy than the control group.

The children were assessed using the Pediatric Motor Activity Log (PMAL) and the Toddler Actual Amount of Use Test. The PMAL was adapted from the adult Motor Activity Log; however the validity of this revised tool has not been established in the paediatric age group. The children were assessed prior to and after the intervention, with follow-up testing three weeks later. Patients in the CIMT group showed a much greater improvement than the control, however the conclusion made that "CI therapy produced major and sustained improvements in motor function..." may not be valid as it is uncertain whether the improvement was due to the actual restraint of the unaffected upper limb or the greater intensity of therapy.

See table 2 for details of paediatric studies.

Table 2 : Summarizing paediatric CIMT studies

Authors	Sample Size	Age Range	Method of CIMT	Type of CIMT	Matched control group	Randomised	Outcome (p <0.05)
Naylor and Bower, 2005	9	18m-5yrs	%	Unrestrained	Y	N	+
Eliasson et al, 2005	41	18m- 4yrs	!!	Mitt	N	Y	+
Taub et al, 2004	18	7 m- 8 yrs	$$	Fibreglass cast	N	Y	+
De Luca et al, 2003	1	1.5 years	$$	Bivalved fibre glass cast	N	N	0
Karman, et al, 2003	7	7yr8m – 17yr10m	**	Mitt	N	N	0
Glover et al, 2002	2	19m, 38m	@@	Forearm splint, POP	N	N	0
Willis et al 2002;	25	1-8yrs	>>	POP	Y	Y	0
Pierce et al, 2002	1	12yrs	++	Mitt	N	N	0
Charles et al, 2001	3	8, 11, 13yrs	**	AS	N	N	0
Crocker et al, 1997	2	2 and 3 years	$$	RHS	N	N	0

>> - indicating wearing CIMT restraint for 1 month, no CIMT treatment
@@ - indicating "wearing mitt as much as possible", 2 hrs physiotherapy and occupational therapy over 3 weeks
!! - indicating CIMT mitt for two hours per day for seven days a week over two months, "encouraged" to use unrestrained hand "as much as possible"
% - indicating 4 weeks of "regular hand therapy" which consisted of the children receiving one hour of bimanual hand activities fortnightly. Thereafter, the children underwent one hour a day of CIMT therapy for four weeks.
** - indicating CIMT everyday for two weeks, 90% of waking hours and shaping therapy six hours a day every weekday for two weeks.
- indicating CIMT everyday for 12 days, 90% of waking hours and shaping therapy for six hours per day for 8 days.
$$ - indicating CIMT everyday for three weeks, 84% of waking hrs and shaping therapy six hours a day over weekdays for three weeks.
++ - indicating CIMT everyday for three weeks, 6 sessions of 2 hours of physiotherapy and occupational therapy
AS – arm sling
RHS – resting hand splint
POP – Plaster of Paris
m – months
yrs - years
Outcome related to CIMT - +: Significant improvement in outcome of CIMT group
0: No significant change
- : Deterioration in CIMT group

2.9.4 Method and application of CIMT

The method of application of CIMT is extremely variable and there have been many different applications and modifications of CIMT therapy from those described by Gordan, Charles and Wolf (2005). Gordan et al (2005) suggests that a child should wear a sling for 6 hours a day for 10 days and during this time receive ongoing shaping and repetition and also suggests that all clinicians must be trained in this specific method. However, Gordan et al (2005) offered no evidence-based research in children to clarify this reasoning.

Examples of the variability of the application are listed below:

- The time period for which the CIMT was applied in the studies mentioned varied from continuously over one month (Willis et al, 2002) to three weeks continuous treatment (Taub et al 2004, Glover et al 2002) to two weeks continuous CIMT with varying hours per day of upper limb training (Karman et al, 2003; Sterr et al, 2002a; Levy et al, 2002).
- The actual amount of time that the physiotherapy treatment "shaping" was done varied from study to study. Shaping periods varied from three (Sterr et al 2002a) to six hours a day (Taub et al 2004, Levy, et al. 2001; Kunkel et al, 1999).This seems to be an extremely labour intensive exercise for the therapist and family, and extremely tiring for the children.
- The materials/ apparatus used for CIMT have varied amongst studies. Willis et al (2002) used mostly plaster of Paris casts in his studies, which remained on the patient's arm continuously, whereas Levy et al (2001) used a "mitt" which could be removed when the patient was doing certain activities (for example bathing and toileting). There seems to be very little difference in the functional outcome of these patients when using different apparatus. The length that the restraint reached on the forearm also varied from study to study.
- Different outcome measures have been used in published studies. In adult studies, both Levy et al (2001) and Sterr et al (2000a) used the Motor Activity Log to assess functional activities such as grooming, feeding and dressing. Taub et al (2004) used the Toddler Arm Use Test and the PMAL to assess his sample patients. The PMAL was modified from the adult Motor Activity Log and has not as yet been validated or standardized for use in paediatric patients. The "Actual Amount of Use Test" and the "Quality of Movement Test"

were used by Karman et al (2003) and De Luca et al (2003) used the PMAL (as mentioned above) as well as the PDFMS. The PDFMS has also been used by Willis et al (2002) and with one of the two patients in the case reports by Glover et al (2002.) The PDFMS has been standardized for children with developmental delay and cerebral palsy between the ages of 0 – 83 months (Hinderer, Richardson and Atwater, 1989). It has been tested and shown to be reliable (Gebhard, Ottenbacher and Lane, 1994) and valid (Provost, Crowe and McClain, 2000; Hinderer et al, 1998) for children in this age group.

2.9.5 Issues raised regarding CIMT

"Constraint-induced movement therapy: time for a little restraint?"

- Siegert and Lord (2004, p110)

There are very few randomised controlled trials in children and adults regarding CIMT. As mentioned previously, most studies have used small sample sizes and many lack appropriately matched control groups that receive equally intense physiotherapy. There is a definite need for more randomised controlled trials to investigate the use of CIMT further (Dromerick, 2003; Siegert and Lord, 2004). It is also unknown whether intensive physiotherapy without restraint would cause similar results as those mentioned in the CIMT studies (Hart, 2005).

As a result of the inappropriate control groups, it is very difficult to determine whether the improvements in function that were seen in patients undergoing CIMT were due to restraining of the upper limb or whether this improvement was related to the intensity of the physiotherapy. This leads to the question of how much "shaping" therapy is actually necessary to show improvement. Sterr et al (2002a) investigated using three hours a day of CIMT compared to six hours a day of therapy. Even though the six hour a day group had more improvement in their hand function, there was still improvement in the three hours per day group. These types of studies, investigating different intensities of CIMT, also need to be conducted to determine the most resource- and cost-effective method of treatment.

All the studies that have been published have been conducted in First World countries. The First World faces extremely different issues to that of developing countries, such as South Africa. In South Africa, there is a lack of resources needed to run such intense CIMT programmes. Taub (2000) criticized group CIMT therapy sessions, saying that supervision needed to be provided by a therapist on a "continuous, one-to-one basis to ensure intensive practice." This statement lacks supporting evidence and is also extremely difficult to implement in a low-resourced environment.

There have only been two articles published discussing how parents and caregivers view the use of CIMT (Page, Levine, Sisto, Bond and Johnston, 2002; Gillot, Holder-Walls, Kurtz and Varley, 2003). Page et al (2002) distributed a pamphlet explaining CIMT and an attached questionnaire asking therapists and patients whether they would want to be involved in CIMT. The questionnaire appeared biased as it only focused on the positive aspects of CIMT and was also directed at therapists and patients who had no direct experience with CIMT. Gillot et al (2003) interviewed two motivated adults who had had strokes and both had taken responsibility for their stroke rehabilitation and then had undergone CIMT. Their views regarding CIMT were favourable, however little conclusive evidence can be drawn from this investigation due to the small sample size and, once again, the obvious positive bias shown in the sample selection.

Understanding how the patients perceive the use of CIMT is important as this is likely to directly affect compliance to the therapy. Parents of the children restrained with CIMT have noticed improvement in their children, however little mention has been made as to the child's levels of frustration or how the parents felt about the actual length and emotional effects of therapy (De Luca et al, 2003). It has been suggested that some children become frustrated and tired using the CIMT (Willis et al, 2002). CIMT has had to be removed for a period of time in such cases and in some more serious cases of distress children have been withdrawn from the study (Karman et al, 2003; Willis et al, 2002).

2.9.6 Ethical issues regarding restraint

In some paediatric studies, children as young as seven months of age have been placed in an upper limb cast for three weeks to one month continuous duration (Taub et al, 2004; Willis et al, 2002). This length of time for a child so young must be frustrating, as well as having potential developmental implications by limiting bilateral hand integration. While the frustration that the child feels might motivate the child to use their affected hand, it is also possible that this frustration might lead to the child refusing to participate partly or fully in the treatment session, as well as refusing to use their affected hand during other daily activities.

In the study by Willis et al (2002) these casts were not removed for one month unless they needed repair. This is worrying as no mention was made of what precautions were taken to prevent the child from serious injury whilst wearing the cast. Of particular concern is that of a child sustaining a fall and being unable to protect himself due to lack of protective extension in the hemiplegic arm.

2.10 Summary of the literature

Cerebral palsy affects numerous children in South Africa, with almost a third of these children presenting with hemiplegia (Rumea-Rouquette et al, 1997). The optimal treatment modality in order to improve these patients' hand function is currently not known.

A detailed understanding of the normal development of hand function as well as the compensatory patterns occurring in children with hemiplegia is vital in order to construct an appropriate treatment plan. Aspects of play constitute the most important means of developing motor skills as well as for higher cortical learning.

There appears to be a lack of scientific evidence regarding the benefits of Neurodevelopmental Therapy and CIMT, despite some reported clinical benefits. It has been suggested that intense therapy of any kind causes an overall improvement in function (Fetters and Kluzik, 1996) and it is unclear whether the CIMT mitt restraining the affected hand or the intense treatment is responsible for the reported benefits of CIMT.

There have been few studies using kinematic analysis to assess upper limb function of children with cerebral palsy; but this tool has been shown to be effective in measuring therapy outcome.

The Peabody Developmental Fine Motor Scale appears to be the best tool for use in investigations of therapy impact, as it has been used in previous CIMT studies; it has been tested for reliability in children with hemiplegic CP (Willis et al, 2002); and is able to detect changes in fine motor function. Other tools have not been validated for this age group or type of disability (Taub et al, 2004).

Paediatric CIMT studies have used different modifications of CIMT technique and application, and different duration and frequency of "shaping" therapy. There is no clear evidence supporting the use of continuous compared to intermittent CIMT.

There are ethical issues relating to the use of CIMT which have not been addressed in previous research studies. These include the emotional and physical tolerance of CIMT by the children and their caregivers.

There are no studies investigating the benefits of an intensive period of group therapy, or the effects and feasibility of performing CIMT on children in the South African context.

Chapter Three: Materials and Methods

3.1 Study Design

3.1.1 Study design

The study design was a prospective pre-experimental study with tests done before and after intervention. In addition there was a smaller prospective, single blinded, randomised controlled clinical trial.

3.1.2 Null hypotheses

Null hypothesis 1:

That there would be no difference in the variables (PDFMS scores, elbow extension, trunk rotation, movement time, movement units, peak velocity and ratio of the time of the first movement unit to the entire movement time) from the initiation of therapy to the end of therapy at two weeks.

Null Hypothesis 2:

That there would be no change in the PDFMS scores from the initiation of therapy or the end of therapy at two weeks to one month after completing the intervention.

Null hypothesis 3:

That there would be no difference between the two groups (CIMT and NDT based physiotherapy group) for the variables mentioned above from the start of therapy to after two weeks of therapy. Nor would there be any difference in the PDFMS score between the two groups at one month post therapy.

3.2 Subjects

All patients with hemiplegia between the ages of two and five years attending out-patient physiotherapy at RCWMCH were eligible for participation in the study. This age group was chosen as they were below school-age and would therefore not be receiving any school physiotherapy intervention. In addition, this group of children did not have any school commitments and this would hopefully allow for greater compliance with attendance at the daily treatment sessions at RCWMCH. In addition, at two years of age children of normal development have mastered most of their gross motor skills. They are also starting to refine their fine hand function tasks (Exner, 1989) (cf. Table 2). Therefore, the change in hand function over two weeks of intervention would be more likely due to the study intervention, than due to natural progression in the development of hand skills

3.2.1 CIMT environment and method

It was initially proposed that the CIMT would be applied under the supervision of the caregiver at the children's homes. This would, however, have invalidated the research results as standardization of intervention could not be ensured. Another major concern for application of household CIMT was the safety risk to the children as they would have decreased protective reactions and poor hand function in daily activities which could lead to accidental injury.

It was therefore decided to perform the study intervention in the controlled environment of RCWMCH thus ensuring continuous professional supervision for child safety and for standardization of the therapy. The physiotherapists involved in the research project and facilitating the treatment sessions, were all employed full-time by the Red Cross Children's Hospital and all had their own large patient caseloads and other work commitments. Due to these commitments they would have been unable to facilitate treatment sessions at other sites.

Alternative additional sites for the research project were investigated. During the early stages of the project it was proposed that children attending nursery classes undergo CIMT therapy at nursery, however during the pilot study when school physiotherapists and teachers were

approached they were not willing to incoporate–any CIMT intervention within the school program and therefore using the nursery/schools for CIMT therapy was not possible. Due to funding limitations the researcher was unable to employ other physiotherapists to facilitate treatment groups at other centres. .

It was not possible to admit study participants to the hospital for two weeks due to limited financial and physical resources. It was decided to ask the patients to attend physiotherapy on an out-patient basis every day for two weeks to ensure compliance in the treatment sessions, in wearing of the CIMT strapping device and to allow for specific, standardized tasks and shaping sessions. However the compliance of the patients attending the sessions was also a concern. It was hoped that providing transport money for the patients and free hospital treatment would be used as an incentive for the parents to attend regularly.

3.2.2 Sample Size

After reviewing the literature, no minimal clinically important differences were identified for the PDFMS outcome measure. The power calculation was obtained by using a nomogram for calculating the necessary sample size (Altman, 1999, pg 456). The sample size was based on the PDFMS and it was calculated that a sample size of 32 patients was required in order to detect a difference between the treatment and control groups of a standard deviation of 4 and with a clinically significant change of 4 (which indicates that the child was able to achieve complete accuracy on two additional items of the subtests after the intervention) and a standardized difference of 1, with a power level of 80%, $\alpha = 0, 05$.

Due to the high rate of attrition noted generally at RCWMCH, all known patients with hemiplegia were contacted via letter and telephonically if the caregiver had provided a contact number.

3.2.3 Inclusion and exclusion criteria for the patient sample

The inclusion and exclusion criteria for the patients were as follows:

Inclusion criteria:

Confirmed hemiplegia as documented in the hospital clinical notes by a paediatrician;

Attending RCWMCH outpatient physiotherapy department;

Between the age of two to five years;

Residing in the Western Cape region, within a 100 km radius of Cape Town;

Ability to follow basic instructions;

Ability to sit independently with sufficient postural control; and

Sufficient passive range of movement to reach an object placed on a table.

Exclusion criteria:

Any circulatory problems;

Botox intervention in the upper limb within the previous year;

Any congenital syndromes;

Blindness (confirmed by paediatrician's notes);

Deafness (confirmed using paediatrician's notes);

Acute brain injury within the previous month;

Uncontrolled seizure activity; and

Severe intellectual disability (confirmed using paediatrician's notes).

3.3 Instrumentation

The following instruments were used to assess the study participants:

1. Peabody Developmental Fine Motor Scale (2nd edition).
2. Vicon Clinical Manager.
3. Questionnaire.

3.3.1 Peabody Developmental Fine Motor Scale (PDFMS)

The primary investigator (EG) conducted all the PDFMS assessments. The children were scored using the PDFMS (2nd edition) three point scoring scale which scores the child with a "2" if the

performance fulfils all the item's criteria, a "1" if the performance clearly resembles, but does not meet the criteria and a "0" if the child does not attempt the item. The total raw scores from the fine motor scale were converted into age equivalent and standard scores for each child.

In order to enhance the reliability of the study, a colleague who was trained in the PDFMS (2nd edition) viewed videotaped assessments of three children and scored them independently from the primary investigator. In all tests that were scored, there was only a 2-point scoring difference in any individual test score (grasp or VMI) between the two persons scoring the test (which accounted for a 5% difference in score). The primary investigator also reviewed the videos to ensure test-retest reliability and there was no change in the scores between the first and second testing. There was a two week period between the first and second test. It was concluded that the instrument, as used by the investigator was reliable.

As mentioned earlier, the validity of the PDFMS norms had been investigated by Hartley-Amien et al, 2005 and South African children from a similar socio-economic background to those in the current study had been found to perform within the predicted norms.

3.3.2 Kinematic analysis using the Vicon Clinical Manager

The children were assessed at the Sports Science Institute in Cape Town by two independent PhD students trained in the use of biomechanical and kinematic analysis. The primary investigator was present at all assessments.

Three dimensional kinematic data was collected at 120 Hz with a 6-camera Vicon clinical manager (VCM) (Oxford Metrics, Oxford, England) while Vicon software (370 Vicon system, 1992) was used to collect and compute the data for all the children. Surface landmarks were placed on the children, which created local embedded reference frames to track limb segment movement. The surface landmarks were placed on the head of the ulna on the hemiplegic side; the lateral epicondyle on the hemiplegic side; bilateral acromion processes and on the superior sternal notch. These points obtained x, y and z co-ordinates for each movement performed and were used to compute the range of motion of trunk and elbow, movement times and the velocity

of the movement. Joint centre locations and anatomic axes were calculated from the data derived.

Using this data the following were established:

- the extension range of the elbow during the reach;
- the rotation of the trunk during the reach;
- the duration of the movement, timed from the beginning to the end point of the reach;
- the peak velocity of the movement; and
- the quality of the reaching movement by determining the number of movement units in the velocity profile and the length of time taken for the first movement unit.

The data was then smoothed by initially smoothing the displacement by multiplying the sum of five consecutive points of displacement by 0.2. This method was also used to calculate smoothed velocity and acceleration. The data was then analysed and graphically illustrated using Microsoft Excel 2000 (Microsoft Corporation).

3.3.3 Questionnaire

A questionnaire (Appendix A) in the language of choice was presented to the caregivers at the two week post treatment assessment. In cases of illiteracy the questionnaire was verbally presented to the caregiver by an interpreter and the answers documented.

The questionnaire was developed by the researcher as the only published questionnaire on the patient's view of CIMT identified was developed for adult patients who had had a stroke and contained questions which were not appropriate for this research thesis (Page et al, 2002). No focus groups were held with other professionals in order to validate the questionnaire. However informal discussions were held with other rehabilitation professionals – which included physiotherapists at Red Cross Children's Hospital, school physiotherapists and a paediatric Masters Physiotherapy student - to gain an understanding of their perceptions of CIMT. Through these discussions it appeared that most physiotherapists had limited knowledge of the CIMT treatment method as it was still a relatively new technique in South Africa. Most professionals

did express concerns regarding CIMT (such as frustration when wearing the CIMT) and these concerns and topics that were discussed were incorporated within the questionnaire. The researcher also considered the various concerns and issues that had been raised in the literature review by other professionals familiar with the CIMT treatment method when developing the questionnaire.

The questionnaire incorporated open and closed questions on how the caregivers/parents viewed the use of CIMT, the way in which the children had participated in the therapy sessions, and the child's level of irritability whilst wearing the CIMT. The care-givers were also asked whether they had any complaints or suggestions regarding CIMT. After the pilot study (Appendix B), discussions were held with the physiotherapists who had been involved in the CIMT treatment regarding how they perceived the use of CIMT, as well as to determine if all the questions were appropriate and clearly understood. It was decided not to change the questionnaire as the concerns/issues that the physiotherapists raised had already been addressed in the questionnaire

An informal interview was conducted with the physiotherapists who facilitated the treatment sessions after completion of data collection.

3.3.4. The Constraint-Induced Movement Therapy apparatus

The CIMT strapping device used in this study was applied to the non affected hand of the child. The strapping device was designed by the primary investigator. It was designed not to cause pain and to allow good circulation to the hand being restrained. The CIMT also allowed movement of the wrist joint of the restrained limb, whilst immobilizing the fingers in flexion.

The strapping was maintained by means of a sock-like apparatus using "VERSAGRIP" – size 1 (6.5 cm x 10m - produced by Smith and Nephew). The VERSAGRIP was placed around the hand. Distal to the fingers, the band was sewn together, with the seam facing outwards, away from the child's fingers. The other end of the strapping fastened mid way up the forearm – with a Velcro strap, which was applied longitudinally – running in the plane of the elbow to the fingers. The strapping remaining distal to the fingers was drawn down and attached to the band on the forearm to encourage flexion of the fingers (Figure 3 – Figure 5).

Figure 3: Lateral view of hand, with CIMT applied: showing fingers flexed with thumb in palm.

Figure 4: Posterior view of hand, showing adjustable Velcro strapping. Note that Velcro is not circumferential.

Figure 5: Anterior view of palmar surface of hand, showing flexion strapping with button to hold strapping

3.4 Procedure

The Human Research Ethics Committee of the Health Sciences Faculty, University of Cape Town approved this study prior to its commencement (REC/REF 359/2003).

All known patients with hemiplegia attending RCWMCH outpatients department (total number = 65) were contacted via letter and/or telephone. These letters were written in the three most commonly spoken languages in the Western Cape – English, Xhosa and Afrikaans. The caregivers were asked to respond to the researcher- either via telephone and/or using the self-

intention was that the tear-off slip with a paid return address envelope would allow for a better response as the caregivers would not need to be made aware of the address of the researcher or spend money on stamps. It was also hoped that as the letters were written in their home language, if the caregiver could not read that the family friend or neighbour would be able to interpret the letter for them. They were also encouraged in the letter to telephone the researcher with any questions that they might have had.

Every attempt was made to contact all caregivers/parents by phone, using an interpreter if necessary, to allow for direct contact of the researcher with the caregiver. However some telephone numbers were no longer operational and some hospital records did not record telephone number of the patients and therefore some patients were unable to be contacted telephonically.

An attempt was made to discuss the research project with patients when they came for routine therapy, however even though discussions were held with a number of caregivers when they came to therapy, it not possible to make direct contact with all caregivers. The reasons for this were was due to the researcher having other conflicting patient appointments, as well as the infrequency and high non-attendance rates of the research patient's appointments. Where the primary researcher was not the principal therapist of the patient the attending therapist was informed of the study and encouraged discuss the research project with their patients, however it cannot be confirmed with any certainty that discussions were held with all the patients in the study.

A small pilot study, described in Appendix B, was completed to assess the practicalities of the study.

Those participants who responded positively to the letter were randomly assigned into two equal groups (NDT based physiotherapy and CIMT groups) using the sealed envelope system. The primary researcher (EG) was blinded to group allocation.

Patients in the same group (either NDT or CIMT group) were then assigned into sub-groups of five children according to their age.

Informed consent was taken from the caregiver or parent in their language of choice before proceeding (see Appendix C1, C2 and C3).

Patients were assessed by the primary investigator on the Friday morning immediately preceding the two weeks study intervention. The children were first assessed to ensure that they fitted the inclusion criteria. Those children who did not fit the inclusion criteria were excluded from the study. The children who did fit the inclusion criteria were then assessed individually without CIMT using the PFDMS (2nd edition) and Vicon analysis.

The children were assessed using the PDFMS in a quiet room with the caregiver present during the assessment. Children were seated at a table with their feet flat on the floor for the assessment. An interpreter was available for those children and parents who were not English-speaking. The caregivers were not permitted to assist the children with any of the activities; however they were allowed to encourage the child during the task.

The children were taken to the University of Cape Town Sports Science Institute for kinematic analysis. All children were seated with their feet firmly supported on the floor or on a block at the correct height. Their buttocks were placed against the back of the chair, with the trunk approximately 10 cm away from the table top. A marshmallow was placed on the table perpendicular to the unaffected shoulder and a full passive length of the hemiplegic arm away from the hemiplegic shoulder. The area was marked with tape with the child's name on it to allow for the marshmallow to be placed on the same spot at each assessment. Each child was told when to start reaching for the marshmallow and this was classified as the start of the reaching movement. The child was asked to fetch the marshmallow and place it in a bowl that was adjacent to the chair where they were sitting. The end of the reach was classified as when the child had touched the marshmallow with his/her hand. See Appendix D for each child's movement velocity profiles.

The children commenced their treatment sessions on the following Monday afternoon. The sessions continued for two weeks in total, with five sessions per week between 13h00 and 15h00 on weekdays. The treatment sessions were held at the RCWMCH outpatient's department and the parents/caregivers had their transport costs paid for them by the researcher. The therapy sessions were based on age-appropriate hand function tasks.

Four physiotherapists facilitated the intervention sessions. Two of the four physiotherapists were NDT trained. The two NDT trained physiotherapists were unable to facilitate all the groups due to other time restraints and work commitments. The other two therapists, while not specifically trained in NDT had worked closely with the NDT trained physiotherapists and use NDT principles in their daily practice. During the research training for the physiotherapists, all the therapists were trained in the CIMT treatment regime, as well as having the NDT concept and principles discussed. NDT handling techniques were also demonstrated and practiced in these training sessions.

During the study each group worked with the same physiotherapist for the two week intervention. The therapists received written instruction on the daily treatment programme from the primary investigator. The primary investigator did not have any contact with the children during the treatment period of the study (see Appendix E for example of treatment session). It was decided that the restraint could only be removed by the facilitator. If the restraint had to be removed more than three times during a therapy session, for whatever reason, the restraint would not be reapplied in that session. If this continued for more than two consecutive days, then the child would be removed from the study, however this would be noted and documented when discussing the results of the study (i.e. intention to treat). A Xhosa interpreter was present in every session to help interpret for the mothers who could not speak English or Afrikaans.

After two weeks the therapy was concluded. The parents and children were asked to return to RCWMCH on the following Monday to be reassessed using the same instrumentation that was used in the initial assessment.

At the two-week assessment the parent or caregiver was given a short questionnaire (see Appendix A) regarding their child's experiences in the study. The primary investigator received completed questionnaires within sealed envelopes and only analysed them after completing other data analysis in order to maintain allocation concealment.

The children were asked to continue with their normal day to day routine for the next month, with no children receiving CIMT or out-patient physiotherapy treatment in the month following the two weeks of intensive treatment. After one month, the children were asked to return for a follow up reassessment using the PDFMS. After this reassessment the children were referred back to their own physiotherapist to continue with routine physiotherapy. This routine physiotherapy would consist of the children receiving an hour physiotherapy session (based on NDT principles, methods and handling techniques) on a once monthly basis. In addition a home exercise programme would be given to the caregiver. The reason for the infrequency of appointments was due to the caregivers' financial constraints limiting access to the hospital as well as resourcing and staffing limitations of the government heath care system.

Subsequent patient treatment groups were conducted in the same way.

3.5 The therapeutic interventions

The children underwent treatment in groups. This was decided upon in order to reduce the costs of treatment and reduce the number of staff hours that were needed for such a research study. Group therapy was also shown be beneficial in other studies investigating the use of CIMT (Gordan et al, 2005; Sterr et al, 2002). The treatment programme was devised according to the current rehabilitation literature and from the researcher's own clinical practice and postgraduate NDT/Bobath training. All tasks and activities were based on play activities, as play is the primary occupation of children (Morrison and Metzger, 2001). The tasks were devised to be age-appropriate for the children in each group, in order to allow for the child to be actively involved and motivated to perform the task and thereby facilitating motor learning (Knox, 1997). The structure of the treatment session remained consistent but the activities the children

were asked to perform (e.g. finger painting) were changed from day to day - with an aim of maintaining the children's attention on tasks during the treatment sessions.

In addition the treatment programme was devised to allow all the children to perform similar tasks in both the CIMT and NDT-based groups, but also included specific tasks which allowed the different principles of CIMT and NDT to be followed. The decision to carry out therapy for two weeks and two hours a day was based on the CIMT principle of intensive practice and restraining the non-affected for a prolonged period of time (Taub 2004). It has already been discussed above as to the reasoning why the children did not undergo longer periods of therapy and restraint. As the CIMT group was to undergo two weeks of therapy, it was also decided to that the NDT-based groups also receive therapy of the same intensity and duration to standardize the amount of treatment sessions that the children were receiving. Intensive NDT was also shown to be effective in the literature (Tsorlakis et al, 2004).

The CIMT programme was based on the CIMT principles which were restraining the non-affected hand and thus forcing the use of the affected hand, the intensive training of the affected hand and the maintaining the non-affected hand with a restraint, and the training of the affected hand for a period of time (Taub et al, 2004). In the CIMT group the child's non-affected hand was restrained using a mitt (as seen in Figures 3 to 5) , for a prolonged period of time (two hours at a time for 5 days a week for two weeks) and intensive training of the hand through task repetition of the affected hand (which included things such as using the affected hand for activities such as activities of daily living and play activities).

The NDT-based therapy was based on the Bobath concept and principles (Mayston, 2001). All the children were observed during their participation in the PDFMS assessment and the children the child's use of the upper limb for reach and grasp when observed during kinematic analysis assessment. All the children had varying difficulties with movement and control of the upper limb, as well as impaired hand function. The aim of the NDT based therapy was to use various techniques to stimulate muscle activity (such as weight bearing, sensory stimulation and appropriate postures and patterns); to facilitate placing muscles on a stretch in order to reduce muscle spindle firing and abnormal reflex activity; to facilitate more normal movement patterns

and then to incorporate these activities into functional activities of daily life (such as washing hands, dressing and play). The children also needed to be provided with opportunities in these treatment sessions to practise these new functions to aid with motor learning. The goals of each child in the therapy group where to gain some improved hand function that was measurable on the PDFMS and that also through the ability to perform everyday activities (such as holding a cup with the affected hand and stirring with the non-affected hand – which is also a task in the PDFMS).

Based on the principles of NDT, it was therefore decided to divide the treatment sessions into components that incorporated techniques and activities to stimulate muscle activity, such as weight bearing, sensory stimulation activities and activities of daily life. Activities were also added to encourage the child to maintain a posture or do an activity that facilitated various muscle groups of the child's upper limb to be placed on a stretch - as this is thought to reduce muscle spindle firing and abnormal reflex activity. Activities were also added to facilitate a more normal pattern of upper limb movement, as well as aid strengthening of upper limb muscles. Passive movements were also performed, as they are performed routinely as a standard of care at Red Cross Children's Hospital and were to allow joints to move through their full range of movement and aid in the prevention of joint contractures. Fine motor activities were incorporated and included sensory and proprioception activities to attempt to give the child increased sensory and proceptive feedback, which might be decreased in children with hemiplegia (Gordan and Duff, 1999). Other activities encouraged the child to practice more refined in-hand manipulation, grasp and reaching patterns and to increase the muscle strength of the hand muscles. The treatment programme also aimed to allow the child to practice various tasks and thereby facilitate motor learning.

In order to standardize treatment the activities were the same the CIMT group; however children in the CIMT group were encouraged to do an activity in any manner, regardless of movement patterns and postures. The NDT-based group physiotherapist did very little direct hands-on therapy with the hemiplegic child due to the group situation. However, the physiotherapist did observe the child's movement patterns and postures throughout the treatment sessions and if the child appeared to be doing an activity in the incorrect manner, the caregiver/parent was shown

how to facilitate their child during the activity to allow the child to use the most appropriate movement patterns and postures. Verbal cues were also given to the child by the physiotherapist regarding issues such as upper limb alignment and hand placement. See Appendix E for a treatment session plan.

The treatment programmes were assessed after the pilot study to determine if it was appropriate for the various groups. The physiotherapists, who facilitated the groups in the pilot study, gave feedback regarding the treatment programmes and adjustments were made to the treatment programmes with an aim to improve the validity of the treatment sessions. See the pilot study (Appendix B) for adjustments that were made to the treatment programme.

3.6 Data analysis

The RCWMCH medical folders of all the study participants were reviewed in order to determine the birth history and the underlying cause of the hemiplegia. Computed tomography (CT) scan results were reviewed in order to determine if there were any similarities between the children.

The data was tested for normality using the Shapiro-Wilk W test[1]. Not all data sets were found to be normally distributed (Table 3). Due to the fact that the data was not normally distributed and that the sample size was small, non-parametric statistical tests were therefore applied.

[1] The Shapiro-Wilk W test is used in testing for normality. If the W statistic is significant, then the hypothesis that the respective distribution is normal should be rejected. The Shapiro-Wilk W test is the preferred normality test because of its good power properties as compared to a wide range of alternative tests (Statistica Electronic Manual).

Table 1: Shapiro-Wilk W test for normality of all variables

Score	Baseline	Two weeks	Six weeks
Age	W = 0.89 p = 0.1		
Grasp	W = 0.96 p = 0.78	W = 0.92 p = 0.27	W = 0.7 p <.001
VMI	W = 0.93 p = 0.33	W = 0.78 p <.001	W = 0.9 p = 0.14
FMQ	W = 0.89 p = 0.098	W = 0.75 p <.001	W = 0.8 p = 0.01
Elbow ROM	W = 0.92 p = 0.29	W = 0.93 p = 0.41	
Trunk ROM	W = 0.68 p <.001	W = 0.94 p = 0.52	
Movement time	W = 0.96 p = 0.74	W = 0.5 p <.001	
Movement units	W = 0.87 p = 0.01	W = 0.85 p = 0.07	
Peak velocity	W = 0.89 p = 0.19	W = 0.9 p = 0.22	
Ratio of first movement unit to movement time	W = 0.77 p = 0.007	W = 0.86 p = 0.1	

Direct comparison of the difference in PDFMS scores i) at the start of the study (baseline) and after two weeks of daily treatment (two weeks); ii) at baseline and one month after study completion (six weeks), were made for all patients and between the intervention (CIMT) and control (NDT based physiotherapy) groups. From the Vicon data, the differences in movement time, number of peaks and valleys in a movement unit, as well as range of elbow extension and trunk rotation at baseline and at two weeks were analysed and compared.

The data was analysed using:

- descriptive statistics;
- within-group dependent variables were compared using Friedman's analysis of variance (ANOVA)[2] and if a difference was detected than a post-hoc Wilcoxon matched pairs

[2] Friedman's ANOVA is a nonparametric equivalent of a one-way repeated measures ANOVA (Statistica electronic manual)

test[3] was used to determine if the difference was between baseline and two weeks, between baseline and six weeks or between two weeks and six weeks;

- between-group independent variables such as the PDFMS scores were compared using the Mann-Whitney U and Kruskal-Wallis tests (both of which are a nonparametric alternative to the t-test for independent variables);
- Spearman rank order non-parametric correlation tests were used to assess relationships between variables;
- Fisher's exact tests[4] were used in the place of Chi-squared when cells contained data values of less than 10 cases;
- Effect size for the magnitude of the treatment effect was calculated using the "Cohen's d" equation[5].

Statistica (Kernel Release 6.1, © StatSoft Inc 1984 – 2003), Analyse-It (Version 1.71, © Analyse-It Software Ltd 2001) and WINKS statistical data analysis (5th edition, © Texasoft Inc) were used for all statistical analyses.

Responses to the questionnaire were divided into themes and these were discussed.

---

[3] The Wilcoxon matched pairs test is a nonparametric equivalent to the t-test for dependent variables (Statistica electronic manual).

[4] The Fisher exact test computes the exact probability under the null hypothesis of obtaining the current distribution of frequencies across cells, or one that is more uneven (Statistica electronic manual). The chi-square test becomes inaccurate when used to analyze contingency tables that contain a small number of cases and therefore the Fisher's exact test is used as it not plagued by inaccuracies due to a small numbers of cases.

[5] Cohen's $d = M_1 - M_2 / \sigma_{pooled}$ where $\sigma_{pooled} = \sqrt{[(\sigma_1^2 + \sigma_2^2) / 2]}$ $r_{Y\lambda} = d / \sqrt{(d^2 + 4)}$

3.7 Ethical considerations

Approval was obtained from the Human Research Ethics Committee of the University of Cape Town's Faculty of Health Sciences (REC/REF 359/2003), the Head of the Physiotherapy Department and the Medical Superintendent of RCWMCH before initiating this study.

Informed written consent was taken from the parent/legal guardian before the child was entered into the study (Appendix C1, C2 and C3). The primary investigator was responsible for taking the consent, by means of an interpreter if necessary. The study procedure was explained to the child at an age-appropriate level. Children participating in the CIMT group were given reasons for strapping the "good" arm. Caregivers were notified of their right to remove their child from the study at any stage.

Although the CIMT strapping device did not cause pain, it was felt that there may be associated discomfort and frustration with having the functional arm effectively removed for the duration of treatment sessions. As a result it was decided to perform CIMT for regular, relatively short periods and not for the sustained application referred to in the literature (Taub, 2000).

If problems arose during the therapy session, such as complaints of discomfort, frustration, and crying, the strapping was removed immediately. If the child was easily consoled, the strapping was reapplied. This process could be repeated three times and if after the third application of the strapping the child was still frustrated, the strapping was removed for the remainder of the session. The child would then be asked to return the following day and if the same behaviour reoccurred the child was removed from the study and a documented account of the incident was noted. During the consent process, caregivers were notified of their right to remove their child from the study at any stage.

At Red Cross Children's hospital, parents are required to pay for treatment of their child (even if the child was under six years old). The amount to be paid is calculated as a percentage of the parents' income and varies from patient to patient. Therefore, treatment costs, as well as,

transport to and from the study venue were paid for by the Research funds, so that the participating families would not incur any additional costs as a result of the study.

The children did not receive "routine" physiotherapy intervention over the six-week study period. The usual physiotherapy routine for children at Red Cross Children's Hospital at the time of the study was approximately one appointment per month. Therefore, most of the children in the study missed one "routine" physiotherapy session; however they were receiving an extra ten upper physiotherapy "upper limb" sessions as part of the study and therefore the withdrawal of routine physiotherapy over the six weeks was considered as ethically acceptable. Two children in the research study needed assistance with walking and all the other children were able to walk independently. In the some treatment sessions, some activities did require the children to maintain four point kneeling, two point kneeling, standing and on occasion some activities involved walking (if the child was able), therefore it is assumed even though gait rehabilitation was not addressed directly in the research project – this might have aided lower limb strengthening.

Occupational Therapy (OT) input of the children in the study group was often infrequent due to staff shortages and children would attend an OT appointment approximately every six weeks. Children were encouraged to attend an OT appointment if it occurred during the time of the research project, however to the researcher's knowledge, none of the 12 patients received OT appointments during the time they participated in the research project.

Patient confidentiality was maintained throughout. No identification of patients will occur in any publication or presentation of the results of this study. Patient details were kept by the primary investigator. All videotapes and photographs that were recorded or taken during the study process were kept securely until analysis and destroyed thereafter, unless explicit consent had been given by the caregivers to use the tapes or photographs for other purposes. Consent for all photographs reproduced in this thesis was obtained from the legal guardian.

This research is justifiable according to the Declaration of Helsinki (2000) in that there was the possibility that a new, effective treatment method for children with hemiplegia would be

identified as a result of this study. This could directly benefit the children involved in the study by improving functional use of the affected arm. In addition, if the intervention were found to be effective and the implementation practical, many children with hemiplegia in the future would benefit.

Chapter Four: Results

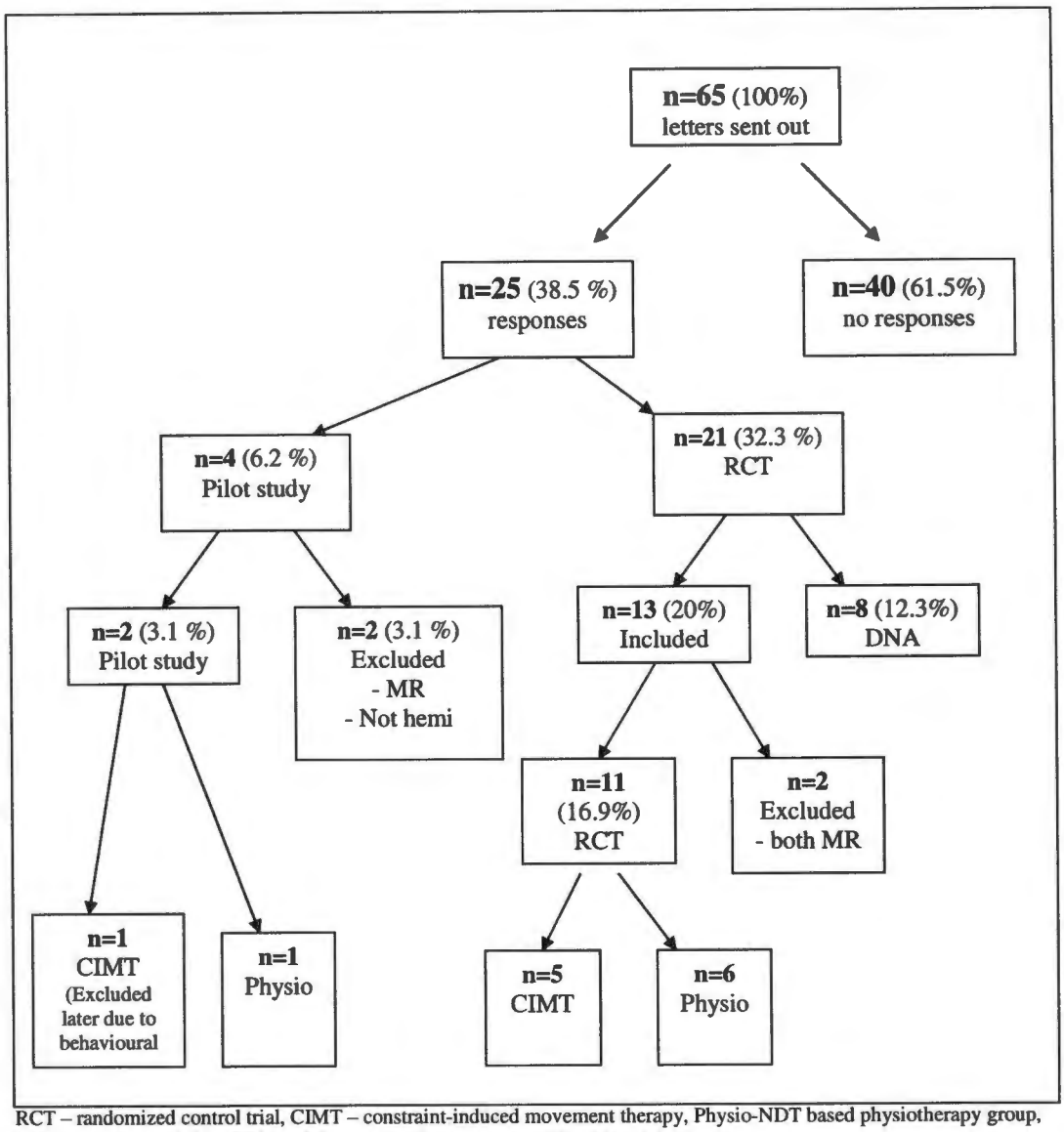
4.1 Sample and patient demographic data

The caregivers of the 65 children with hemiplegia who were identified through the Red Cross Hospital registers were contacted by letter. Where a telephone number was provided, these caregivers were also contacted telephonically.

Twenty-five caregivers responded to the letter stating their willingness to participate in the study. Of these 25 respondents, four were randomly selected, using a sealed envelope system, to participate in the pilot study (see Appendix B for full details of pilot study). The 21 remaining children were randomised using a sealed-envelope system into CIMT and control groups. Of these 21 patients who agreed to participation in the study, 13 patients arrived for assessments. Two of these patients were excluded due to severe intellectual disability, as they were unable to follow basic instructions given to them during the standardized assessments – leaving a total of 11 patients participating in the study.

Due to the small sample size, it was decided to include the pilot study patient who completed the full two weeks of therapy in the main study population. This was found to be acceptable, as the protocol was found to be satisfactory and did not change from the pilot to the main study.

Figure 6 presents a flow-chart of subject recruitment, participation, and exclusion. The effective number of participants was 12, five of which were in the CIMT group and seven in the NDT based physiotherapy group.



RCT – randomized control trial, CIMT – constraint-induced movement therapy, Physio-NDT based physiotherapy group, MR – mental retardation, DNA – did not arrive for assessment, Hemi-hemiplegia.

Figure 6: Patient Sample Flow Chart

The mean age of study patients was 44.6 months with a range of 32 to 63 months, and a standard deviation of 10.78 months.

Eight of the children had right-sided hemiplegia and four had left-sided hemiplegia. The cause of CP was known in five (41.6 %) patients and unknown in seven (58.3%). Two of these former five children had Tuberculosis Meningitis (TBM) acquired hemiplegia

Birth history was available in 11 of the 12 patients. Five children were born prematurely, before 36 weeks gestational age, and six children were born at term. No relationship was apparent between the gestational age and CT scan results. Five children showed cerebral ventricular enlargement, two children were shown to have intraventricular haemorrhage and one child was shown to have a middle cerebellar artery infarct on CT scan. Table 4 presents the patients' data.

Subjects attended a median of 10 therapy sessions (range 8 – 10). No child was excluded from the CIMT group on the basis of irritability or non-compliance with the restraint.

Table 2 : Patient data

No	Gender	Age (m)	Birth Hx	Cause	CT scan results	Side of hemiplegia	Group
1	M	39	Term	TBM	No CT	L	A
2	F	32	Not known	Idiopathic	↓ periventricular matter Enlarged L lateral ventricle	R	A
3	M	35	Preterm	Intraventricular haemorrhage (IVH)	IVH – Grade 4, hydrocephalus	R	A
4	F	58	Term	Seizures - 45 months	Infarcts R basal ganglia. Cyst-like structure between capsule of ventricles	L	A
5	F	59	Preterm	TBM - 13 months	L basal ganglia infarcts	R	A
6	M	34	Term	GBS meningitis- 2 days old	Enlarged ventricles Hydrocephalus	R	B
7	M	44	Term	Idiopathic	Ventricular System prominence Small L hemisphere Mild central nuclear thickening	L	B
8	M	35	Preterm	IVH, apnoea	IVH-Grade 3, L side Borderline bilateral IVH-Gr 2	R	B
9	M	47	Term	Unknown	No CT	R	B
10	M	63	Preterm	Idiopathic	Infarct in R parietal area Ventricular prominence	L	B
11	F	37	Term	Meconum aspiration	L middle cerebral artery infarct L ventricle dilated	R	B
12	M	47	Preterm	Unknown	No CT	R	B

M – male; F- female; GBS – Group B Streptococcal meningitis– ; L-left; R-right; IVH- intraventricular haemorrhabge, m – months, Group A – CIMT, Group B – NDT-based group

4. 2 Patient assessment data

From the data that was captured during kinematic analysis, velocity profiles were completed on each patient to show the number of movement units (described earlier as one movement unit consisting of one acceleration and one deceleration) during the reach. A change in acceleration was regarded as being when the child's velocity changed by more than 20 mm/sec. The velocity profiles were smoothed twice, in an attempt to decrease the amount of interference during data capturing.

The velocity profiles were graphically shown from the starting position, to the child taking the marshmallow and then returning to the starting position (see Appendix D for all the velocity profiles). These velocity profiles were constructed for each child to show graphically whether there was an improvement in the quality and smoothness of the reaching pattern after treatment. An example of the velocity profiles is shown below (Figure 7).

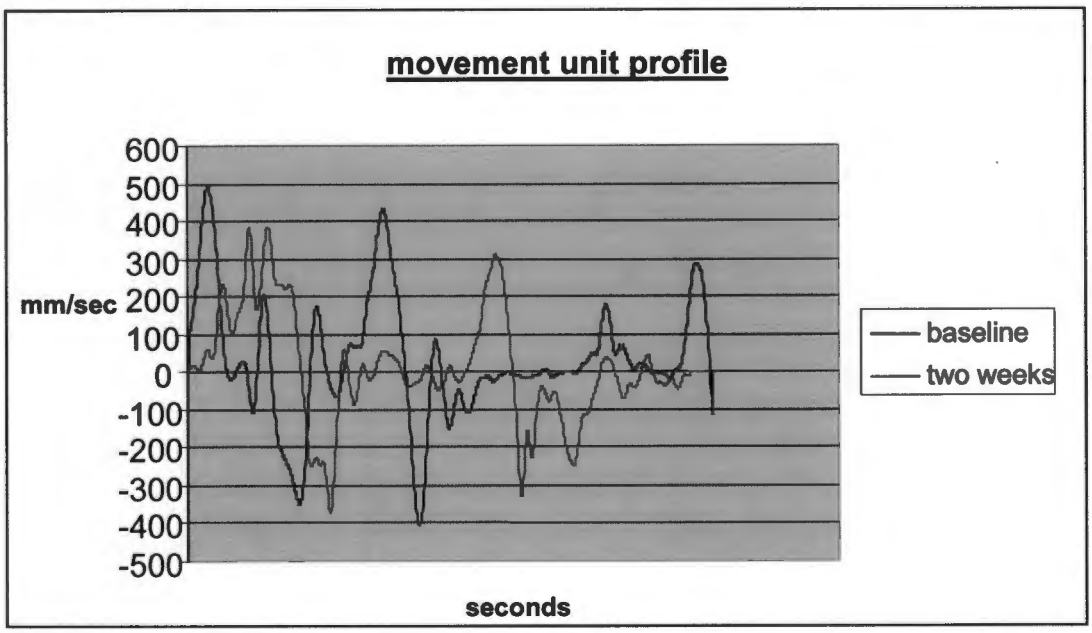


Figure 7: Example of velocity profile- showing changes in the smoothness of reach from before treatment (baseline) to after treatment (two weeks).

4.3 Results of intensive physiotherapy for all patients

The results of the different tests for all subjects are presented in Table 5. This data was taken initially at baseline, two weeks later (after therapy was completed) and six weeks after initial assessment. Four (33.3%) patients did not return for the six week assessment. Kinematic analysis was not retested again at six weeks, due to the parents having time constraints for the follow up assessments.

One patient was excluded from analysis of changes in movement time as he was repeatedly distracted whilst reaching for the object at the post-treatment assessment, leading to an outlier value of movement time of 21.87 seconds. It was not possible to collect data for movement time for one other subject post therapy, as the Vicon cameras did not collate the data from one of the surface landmarks placed on the child and therefore the subject's movement time could not be calculated.

The table shows all the PDFMS scores: i) grasp, ii) VMI and iii) FMQ as well as the kinematic data which includes i) the degrees of elbow extension in the hemiplegic arm, ii) the change in trunk rotation from the beginning to the end of the reaching movement, iii) the number of movement units in the reach, iv) the peak velocity of the reach and v) the ratio of the time taken for the first movement unit to the total movement time.

No correlations were found between the age of the children and any of the baseline parameters ($p > 0.1$ for all). Using the Mann-Whitney U test, it was found that none of the baseline variables were affected by gender, side of hemiplegia, term or preterm birth, or whether the CP was acquired or not ($p > 0.08$ for all). See Appendix F for full details.

Table 3: Showing combined data for all patients. Data are presented as median (interquartile range). N=12 at baseline, N=12 at two weeks and N=8 at six weeks.

Score	Baseline	Two weeks	Six weeks	p-value (baseline-2 wks)	p-value (2 weeks to 6 weeks)	p-value (baseline - 6 weeks)
Grasp (PDFMS score)	28.5 (24.5 – 37.5)	33.0 (27.0 – 40.0)	27 (27.0 – 101.0)	**0.016**	1	**0.03**
VMI (PDFMS score)	71.0 (63.5 – 84.0)	78.0 (71.0 – 84.5)	77 (74.5 – 101.0)	**0.018**	0.32	**0.03**
FMQ (PDFMS score)	53.5 (49.0 – 62.5)	52.0 (50.0 – 65.5)	55 (53.5 – 101.0)	0.31	0.75	0.06
Elbow (degrees)	122.44 (110.59 – 139.38)	125.09 (114.73 – 133.32)	-	0.19	-	
Trunk (degrees)	34.01 (18.70 – 36.16)	33.27 (25.93 – 40.22)	-	0.17	-	-
Movement time (seconds)	2.11 (1.28 – 3.18)	1.95 (0.96 – 2.58)	-	0.19	-	-
MU's (mm/sec^2)	13.0 (9.0 – 15.0	10.0 (9.0 – 12.0)	-	0.16	-	-
Peak velocity (mm/sec)	479.28 (296.72 – 1027.40)	805.8 (517.03 – 948.12)	-	0.08	-	-
Ratio of 1st mu:mt (seconds)	0.28 (0.21 – 0.32)	0.35 (0.25 – 0.88)	-	0.24	-	-

VMI – visual motor intergration raw score, FMQ – fine motor quotient, Elbow ext – elbow extension (degrees), trunk rot – trunk rotation (degrees), movt time-movement time (secs), no of MU's – number of movement units, peak velocity in mm/sec, ratio of 1st mu:mt - ratio of time of first movement unit to total movement time.

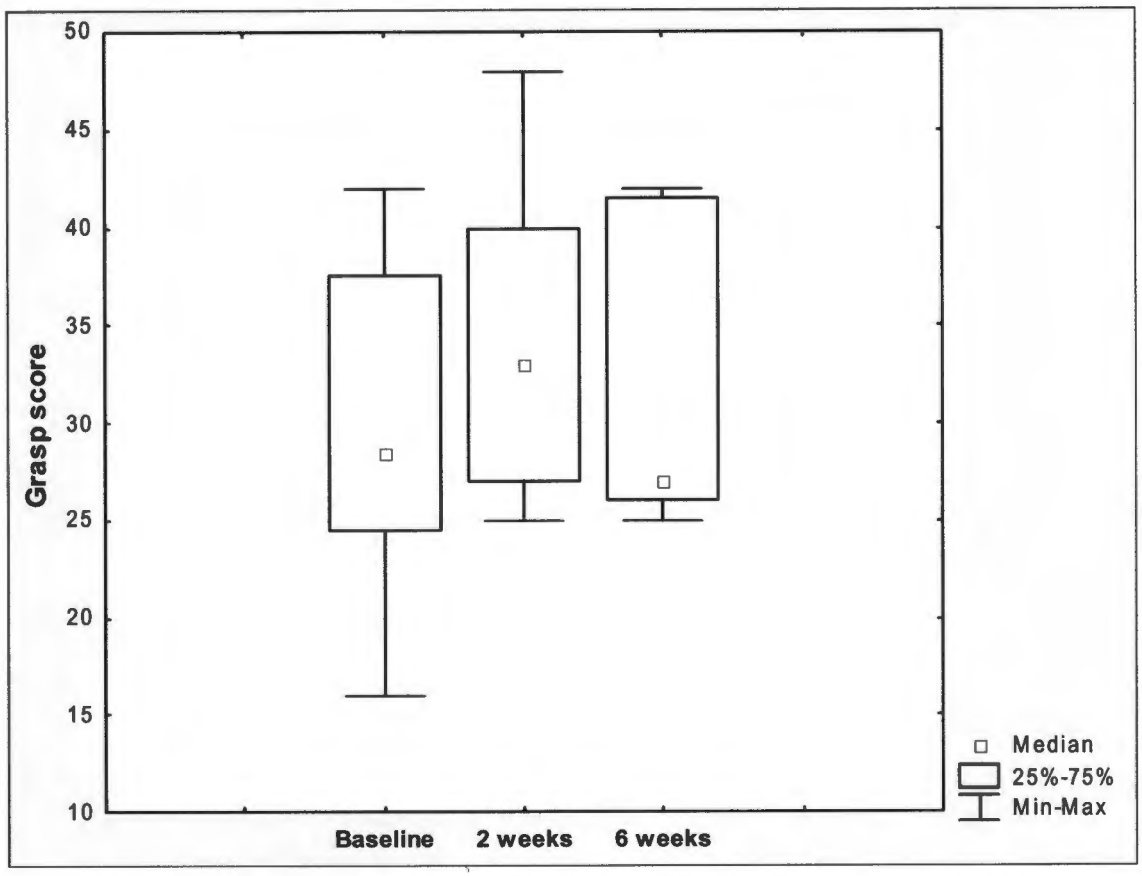


Figure 8: Plot of change in grasp from baseline to six weeks. Friedman's ANOVA ($p < 0.02$).

Figure 8 illustrates the improvements occurring in grasp from baseline to two weeks ($p<0.02$) and from baseline to six weeks ($p = 0.03$), with no change between two weeks and six weeks ($p = 1$)

Figure 9 illustrates the change in the grasp of individual. The graph shows the individual's raw grasp scores at baseline, two weeks and at 6 works. All individuals made an improvement in grasp over the first two weeks. Some patients could not be plotted on the graph for grasp at six weeks as they did return for their six week assessment.

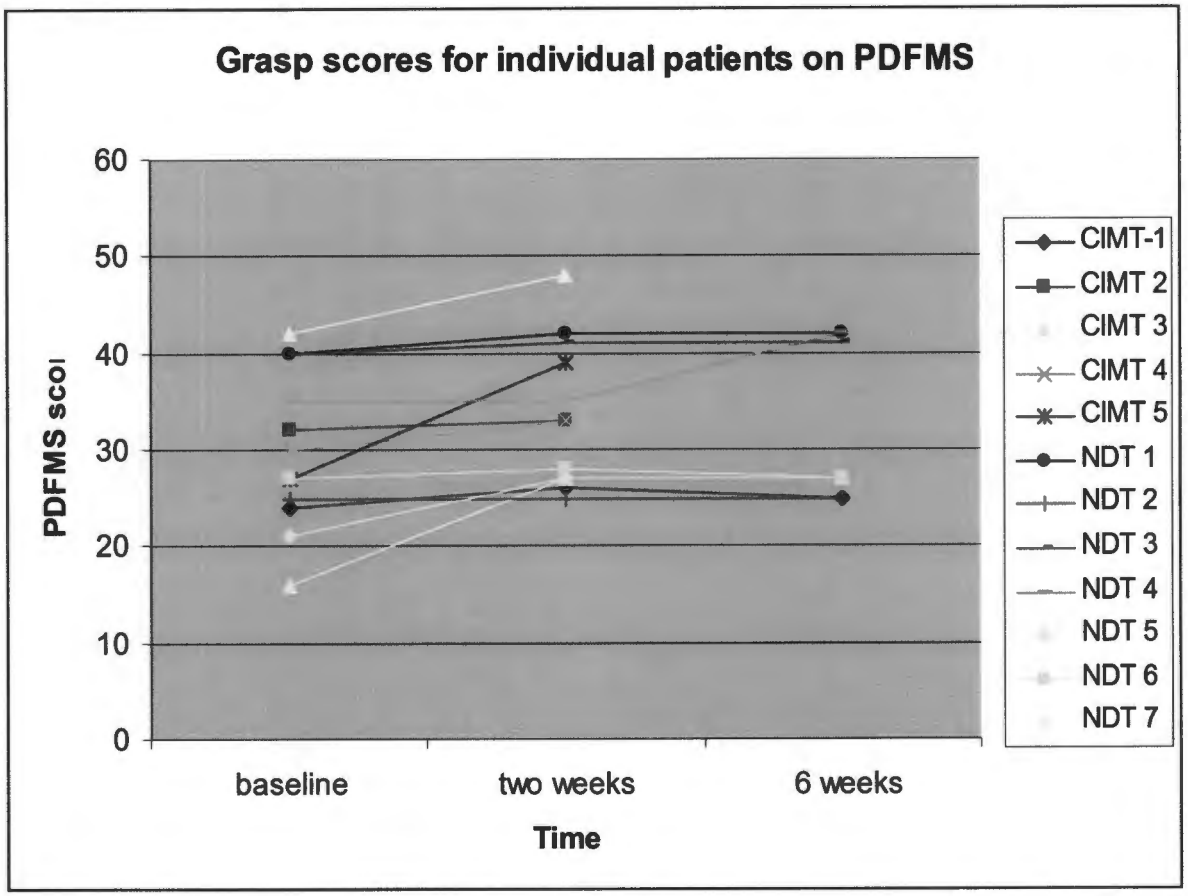


Figure 9: Showing change in grasp scores for all patients.

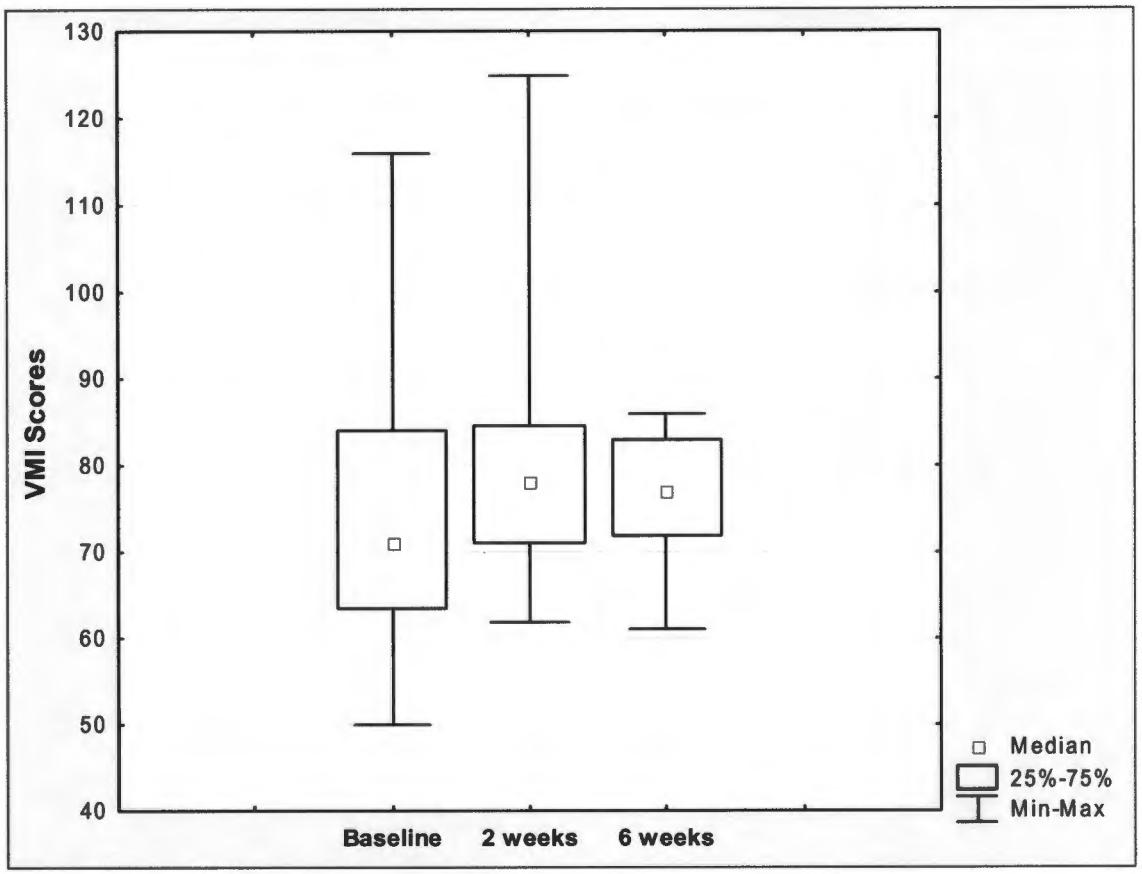


Figure 10: Changes in VMI throughout study period. (Friedman's ANOVA p = 0.03).

Figure 10 presents the improvement in VMI from baseline to two weeks ($p < 0.02$), and from baseline to six weeks ($p = 0.03$), with no change from two weeks to six weeks ($p = 0.32$). All but one of the children improved their VMI score results. This child was noted to be unwell on the day of the post treatment assessment and this could have influenced her score results.

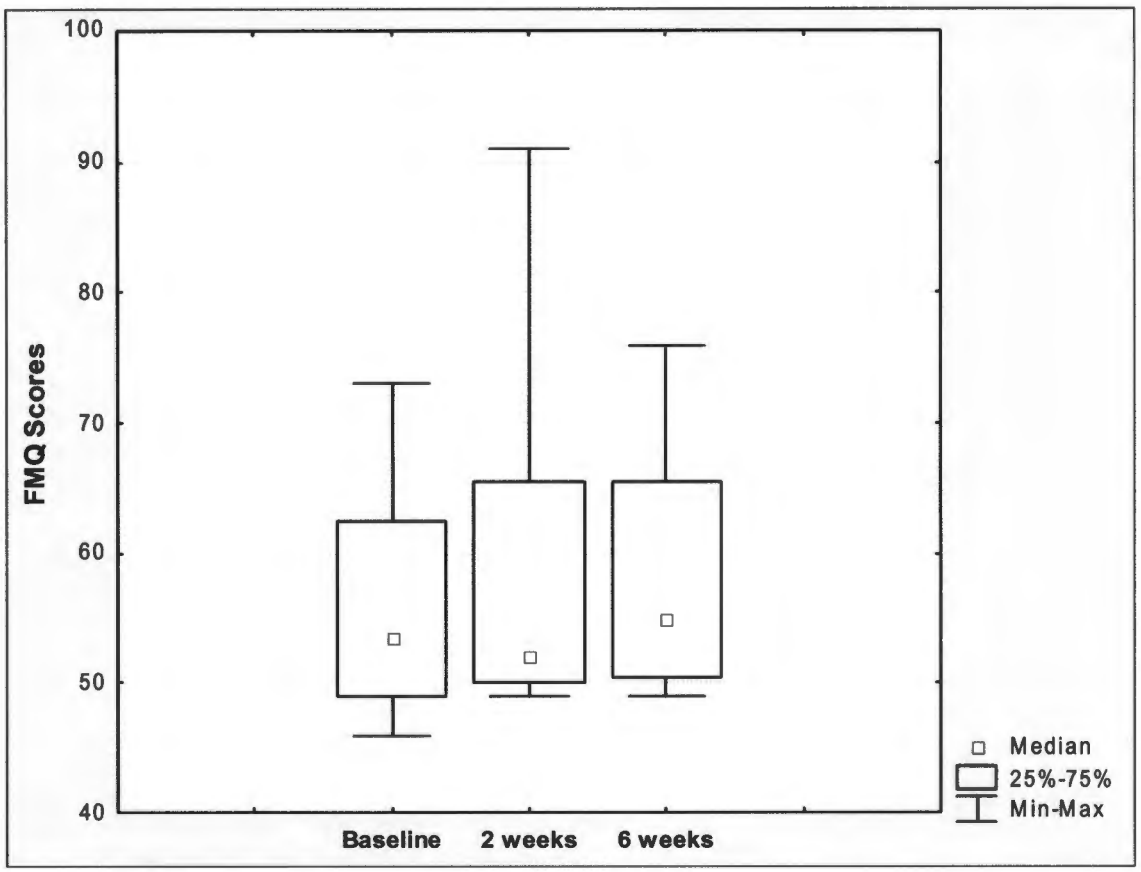


Figure 9: Changes in FMQ during the study period (Friedman's ANOVA, p = 0.06).

Figure 11 presents the changes occurring in FMQ from baseline to six weeks (p = 0.06), with no change from baseline to two weeks (p = 0.31) or from two weeks to six weeks (p = 0.75). All patients either maintained or improved their FMQ scores.

No correlations were detected between any of the Vicon and PDFMS data, except for the bold print correlations in Table 6.

.

Table 6: Correlations between variables at baseline and two weeks. R is Spearman's R, significant correlations are in bold.

	VMI baseline	VMI two weeks	FMQ baseline	FMQ two weeks	Elbow ROM baseline	Elbow ROM two weeks	Trunk ROM baseline	Trunk ROM two weeks	MT baseline	MT two weeks	MU baseline	MU two weeks	Maximum velocity baseline	Maximum velocity two weeks	MU:MT baseline	MU:MT two weeks
Grasp baseline	**R = 0.58 p = 0.046**		**R = 0.89 p=0.0001**		R = -0.02 p = 0.96		R = 0.3 p = 0.36		R=0.1 p = 0.76		R = -0.45 p = 0.17		R= 0.13 p = 0.69		R = -0.34 p = 0.3	
Grasp two weeks		R = 0.56 p = 0.06		**R = 0.68 p = 0.02**		R = 0.21 p = 0.5		R = -0.47 p = 0.12		R = 0.32 p = 0.3		R = 0.03 p = 0.92		R = -0.03 p = 0.93		R = -0.07 p = 0.83
VMI baseline			**R = 0.58 p = 0.049**		R = -0.03 p = 0.9		R = 0.58 p = 0.06		R = -0.14 p = 0.68		R = -0.67 p = 0.03		R = 0.47 p = 0.14		R = 0.00 p = 0.98	
VMI two weeks				R = 0.51 p = 0.09		R = -0.03 p = 0.92		R = -0.2 p = 0.5		R = 0.3 p = 0.33		R = 0.05 p = 0.89		R = 0.45 p = 0.18		R = -0.02 p = 0.94
FMQ baseline					R = 0.18 p = 0.59		**R = 0.61 p = 0.04**		R = -0.2 p = 0.56		**R = -0.63 p = 0.03**		R = 0.19 p = 0.57		R = 0.00 p = 0.99	
FMQ two weeks						R = -0.01 p = 0.97		**R = -0.72 p = 0.008**		R = -0.06 p = 0.84		R = 0.2 p = 0.6		R = 0.16 p = 0.67		R = -0.0.3 p = 0.93
Elbow ROM baseline							R = 0.2 p = 0.54		R = 0.1 p = 0.77		R = -0.07 p = 0.83		R = -0.19 p = 0.57		R = -0.17 p = 0.61	
Elbow ROM two weeks								R = -0.1 p = 0.75		**R = 0.63 p = 0.03**		R = 0.3 p = 0.3		R = -0.21 p = 0.56		R = -0.63 p = 0.12
Trunk ROM baseline									R = -0.41 p = 0.2		**R = -0.83 p = 0.001**		R = 0.54 p = 0.1		R = 0.13 p = 0.71	
Trunk ROM two weeks										R = -0.08 p = 0.81		R = -0.33 p = 0.32		R = 0.14 p = 0.69		R = 0.15 p = 0.65
MT baseline											R = 0.25 p = 0.46		R = 0.09 p = 0.79		**R = -0.73 p = 0.01**	
MT two weeks												R = 0.36 p = 0.28		R = 0.07 p = 0.8		R = -0.48 p = 0.13
MU baseline													**R = -0.7 p = 0.008**		R = -0.06 p = 0.85	
MU two weeks														R = -0.22 p = 0.52		R = -0.05 p = 0.87
Maximum velocity baseline															R = -0.02 p = 0.96	
Maximum velocity two weeks																R = 0.05 p = 0.9

The correlations between the changes in Vicon variables from baseline to two weeks are presented in Table 7.

Table 7: The correlations between the changes in variables from baseline to two weeks. R is Spearman's R; significant correlations are in bold.

	VMI change	FMQ change	Elbow ROM change	Trunk ROM change	MT change	MU change	Maximum velocity change	MU:MT change
Grasp change	R=0.21 p=0.5	R=0.11 p=0.74	R=-0.22 p=0.52	R=-0.11 p=0.76	**R=0.78 p=0.005**	R=0.34 p=0.34	**R=0.67 p=0.035**	R=-0.02 p=0.9
VMI change		**R=0.61 p=0.034**	R=0.46 p=0.15	R=-0.34 p=0.34	R=0.17 p=0.62	R=-.10 p=0.78	R=0.60 p=0.065	R=-0.35 p=0.32
FMQ change			R=0.17 p=0.61	R=0.28 p=0.43	R=-0.14 p=0.68	R=0.25 p=0.49	R=0.41 p=0.24	R=-0.09 p=0.81
Elbow ROM change				R=-0.08 p=0.83	R=-0.01 p=0.98	R=-0.12 p=0.74	R=0.30 p=0.4	**R=-0.68 p=0.03**
Trunk ROM change					**R=-0.67 p=0.05**	R=-.13 p=0.75	R=-0.33 p=0.38	R=0.07 p=0.86
MT change						R=-0.05 p=0.88	R=0.58 p=0.08	R=-0.36 p=0.31
MU change							R=-0.29 p=0.4	R=-0.24 p=0.49
Maximum velocity change								R=0.05 p=0.88

As shown in table 6, the grasp at baseline correlated significantly with VMI baseline score (p=0.046, R=0.58) and the FMQ score at baseline (p=0.0001, R=0.89). The grasp score at two weeks correlated with FMQ at two weeks (p=0.02, R=0.68). The FMQ score at baseline correlated significantly with the VMI score at baseline (p=0.049, R=0.58), with trunk rotation at baseline (P=0.04, R=0.61) and the number of movement units at baseline (p=0.03, R=-0.63). The FMQ score at two weeks correlated significantly with trunk rotation at two weeks (p=0.04, R=-0.72). The range of elbow extension at two weeks correlated significantly with movement time at two weeks (p=0.03, R=0.63). The movement time at baseline correlated significantly with the ration of the first movement unit to movement time at baseline (p=0.01, R=-0.73). The

number of movement units at baseline correlated significantly with maximum velocity at baseline (p=0.008, R=-0.7) and with trunk rotation at baseline (R=-0.83, p=0.001).

As shown in table 7, the change in grasp significantly correlated with the change in movement time (p=0.005, R=0.78) and the change in maximum velocity (p= 0.0035, R=0.67). The change in VMI correlated significantly with the change in FMQ over two weeks (R=0.61, p= 0.034). The change in elbow range of movement also correlated significantly to the change in the first movement unit to movement time ratio over two weeks (R=-0.68, p= 0.03). The change in trunk rotation also correlates with the change in movement time (R=-0.67, p= 0.05).

Using the Mann-Whitney U test, Table 8 presents the effects of gender, birth history (whether preterm or term), the side of hemiplegia and the aetiology of CP (acquired or non-acquired) on the changes of the measured variables from baseline to two weeks.

Table 8: Effects on outcome measures. Data are presented as p values and significant changes in parameters are in bold.

	Change in parameters from baseline to two weeks								
	Grasp	**VMI**	**FMQ**	**Elbow ROM**	**Trunk ROM**	**Max velocity**	**MT**	**MU**	**MU:MT**
Gender	0.8	0.07	0.07	0.23	0.76	0.76	0.64	0.61	0.35
Birth history	**0.05**	0.08	0.42	0.61	0.19	**0.01**	**0.02**	0.28	1.0
Hemi side	0.9	0.3	0.6	0.41	0.66	0.26	0.93	1	0.11
Aetiology	0.55	0.15	0.22	**0.03**	1	0.4	0.56	0.72	1

VMI – visual motor integration raw score, FMQ – fine motor quotient, Elbow ext – elbow extension (degrees), trunk rot – trunk rotation (degrees), MT-movement time (secs), MU – number of movement units, peak velocity in mm/sec, MU:MT - ratio of time of first movement unit to total movement time.

Subjects born prematurely had a greater change in grasp, maximum velocity and movement time, than those born at term, and subjects with idiopathic CP showed a greater change in elbow ROM than those who acquired CP postnatally.

4.3.1 Effect size of intensive physiotherapy for all patients

The effect size was calculated using Cohen's d (magnitude of effect size) formula. An effect size of less than 0.4 is said to be a small effect size, between 0.5 and 0.8 is a medium effect size and larger than 0.8 is said to be a large effect size. A negative number for movement time, degrees of trunk rotation and number of movement units shows a positive effect (Cohen, 1988).

The effect sizes for the whole population sample are shown in Table 10. There were positive medium effects for grasp and a reduction in the number of movement units between baseline and two weeks. All effects between two to six weeks were small and in the direction of decreased performance.

Table 9: Effect size of treatment on participants. N=12 at baseline, N=12 at two weeks and N=8 at six weeks.

Change in score	**Overall effect size from 0-2 weeks**	**Size of effect**	**Overall effect size from 2-6 weeks**	**Size of effect**
Grasp	0.46	Positive small effect	-0.22	Negative small effect
VMI	0.34	Positive small effect	-0.21	Negative small effect
FMQ	0.27	Positive small effect	-0.04	Very small negative effect
Elbow extension	0.11	Positive small effect		
Trunk rotation	-0.06	Very small positive effect		
Movement time	0.31	Negative small effect		
Movement units	-0.56	**Positive medium effect**		

4.4 Differences between CIMT and NDT based physiotherapy groups

In the CIMT group, the mean age was 44.6 months +/- 12.93 months standard deviation (SD) and in the NDT based physiotherapy group, 43.85 months +/- 2.16 SD ($p = 0.55$). Patients in the CIMT group had an attendance of the physiotherapy sessions of 9.8 days ± 0.44 (mean +/- SD) and the NDT based physiotherapy group had an attendance of 9.14 days ± 0.89 ($p = 0.19$). The Mann Whitney U indicated no difference between these parameters in the two groups.

The Fisher's exact test detected no difference between patient groups with regard to gender ($p = 0.57$), age ($p = 0.55$), side of hemiplegia ($p = 0.15$) or acquired versus congenital hemiplegia ($p = 0.31$).

The data for both separate groups are shown in Table 9 (see following page). The PDFMS data (grasp and VMI raw scores, FMQ score) was taken initially at baseline, two weeks later after therapy was completed and at one month follow-up (six weeks). Only two of the five (40%) subjects from the CIMT group and six (85%) of the seven NDT based physiotherapy group subjects arrived for the six week follow-up assessment.

The kinematic data (using the Vicon clinical manager) for both groups is also shown in Table 9. This includes the degrees of elbow extension in the hemiplegic arm and the change in trunk rotation from the beginning to the end of the reaching movement, the number of movement units in the reach, the peak velocity of the reach and the ratio of the time taken for the first movement unit to the total movement time.

One patient in the CIMT group (subject e) was excluded from analysis of changes in movement time as he was repeatedly distracted whilst reaching for the object at the post-treatment assessment, leading to an outlier value of movement time of 21.87 seconds. As mentioned earlier, it was not possible to collect data for movement time for another CIMT patient post therapy.

Table 10: Differences between group scores. Data are presented as median (interquartile range). For the CIMT group: N=5 at baseline, N=5 at two weeks and N=2 at six weeks. For the NDT based physiotherapy group: N=7 at baseline, N=7 at two weeks and N=6 at six weeks.

Score	CIMT group	Physio group	P-value (difference between groups)	P-value – difference in change from baseline to two weeks	P-value: difference in change from baseline to six weeks	P-value: Difference in change from two weeks to six weeks.
Grasp -before therapy	27 (24 – 30)	35 (25 – 40)	0.19	-	-	
Grasp -after therapy	33 (27 – 33)	35 (27 – 42)	0.42	0.1255	-	
Grasp – one month	26 (25 – 27)	34 (27 – 42)	0.23	-	0.64	0.64
VMI –before therapy	71 (64 – 75)	71 (63 - 88)	0.75	-	-	
VMI –after therapy	72 (70 – 78)	80 (72 – 86)	0.26	0.66	-	
VMI – one month	72 (71 – 73)	80.5 (76 – 83)	0.18	-	0.43	0.86
FMQ – before therapy	52 (49 – 52)	58 (49 – 70)	0.25	-	-	
FMQ – after therapy	52 (51 – 52)	58 (49 – 76)	0.17	0.25	-	
FMQ – one month	53.5 (52 – 55)	58 (49 – 70)	0.62	-	1	0.64
Elbow ext - before therapy	116.65 (114.79 – 147.05)	125.77 (106.54- 133.92)	0.58	-	-	
Elbow ext –after therapy	129.44 (118.38 – 135.27)	122.24 (114.39 – 131.37)	0.57	1.0	-	
Trunk rot – before therapy	24.26 (18.70 – 34.01)	35.12 (31.73 – 40.98)	0.2	-	-	
Trunk rot –after therapy	33.36 (33.18 – 34.12)	32.21 (13.89 – 51.43)	0.68	0.69	--	
Movement time – before therapy	2.11 (1.28 – 2.39)	2.40 (1.38 – 3.18)	0.71	-	-	
Movement time - after therapy	1.55 (0.8 – 11.8)	2.21 (0.96 – 2.58)	0.85	0.09	-	
No of MU's - before therapy	15 (13 – 23)	10.5 (8 – 12)	0.4	-	-	
No of MU's - after therapy	11 (7.5 – 17)	9 (9 – 11)	0.23	0.41	-	
Peak velocity – before therapy	296.72 (127.31 – 494.03)	542.49 (479.28 – 1027.40)	0.2		-	
Peak velocity - after therapy	523.66 (517.03 – 765.79)	886.37 (824.62 – 963.57)	0.07	0.9	-	
Ratio MU: MT –before therapy	0.32 (0.27 – 0.35)	0.22 (0.21 – 0.28)	0.23	-	-	
Ratio MU: MT -after therapy	0.62 (0.32 – 0.94)	0.4 (0.15 – 0.66)	0.72	0.73	--	

VMI – visual motor integration raw score, FMQ – fine motor quotient, Elbow ext – elbow extension (degrees), trunk rot – trunk rotation (degrees), movt time-movement time (secs), no of MU's – number of movement units, peak velocity in mm/sec, ratio of time of first movement unit to movement time.

It is clear from Table 9 that there was no significant difference between any of the parameters measured between the CIMT and the NDT based physiotherapy group. CIMT did not have a lesser or greater effect on outcome than that of the NDT based physiotherapy.

The differences between the effect sizes of the CIMT and NDT group are shown in the table 11 below:

Table 11: Difference in effect sizes for the CIMT and NDT group

Changes in variables over two weeks	CIMT group	NDT-based group
Grasp	0.4479 (small positive effect)	-0.131 (small negative effect)
VMI	-0.197 (small negative effect)	-0.179 (small negative effect)
FMQ	0.023 (small positive effect)	-0.172 (small negative effect)
Elbow extension	-0.0188 (small positive effect)	-0.186 (small positive effect)
Trunk rotation	-0.55 (small positive effect)	0.190 (small positive effect)
Movement time	-0.297 (small positive effect)	-0.179 (small positive effect)

There appears to no difference between the effect of CIMT group therapy versus NDT-based group physiotherapy on the variables over two weeks.

4.5 The parents' questionnaire

The questionnaire was primarily aimed at those caregivers of the children who wore the CIMT; however it was found that most of the NDT physiotherapy group parents also documented on the questionnaire how they felt their children had participated in the treatment sessions and how they felt the sessions had benefited their children. Comments and suggestions from both sets of parents were also made to the researchers which have been included below.

The responses from the parents were as follows:

All 12 parents/caregivers felt that their children participated well in the therapy sessions. One parent mentioned that her child enjoyed being in the group and was motivated by seeing other children doing the same type of activities. Most parents during the assessment mentioned that their children had enjoyed being in the group and often asked about the other children even after the therapy had finished.

All five parents in the CIMT group felt that there was an improvement in their child's hand function. All seven of the NDT based physiotherapy group parents also felt that their children improved following treatment. Caregivers responded with comments such as "she is using her hand more and she is responding quickly", "she can hold small objects with the [affected] hand", and, "she can do and undo buttons now"; "using hand more at home now and more open", and "he can now lift up his affected arm to take off his jersey." Other responses included: "...because the hand is looking well, if he wants to open it then he opens it, if he want to close, then he closes it", "the more he uses the hand, the better."

When asked if the children wearing the CIMT got irritated, four of the five parents reported that their child did get frustrated. Some of their responses were: "frustrated", "tried to take it off sometimes", "got frustrated and angry because they are used to using the other hand", "never tried to take off CIMT but did get frustrated and tired". However no parent stated that the child required the CIMT to be removed for extended periods

Most of the parents found that their children and themselves were getting tired after two weeks of therapy. Two parents stated that the actual travelling to the hospital every day was quite tiring

Six parents (of both groups) suggested that both forms of intensive treatment should be continued in the future.

4.6 Interview with the group facilitators

The facilitators of both the NDT based physiotherapy group and CIMT groups felt that some children did not participate well in the therapy sessions and had "short attention spans", "were naughty" and "threw regular temper tantrums."

They also felt that even though the therapy sessions were structured and organized, they tended to improvise and modify activities in order to keep the children's attention and interest in the activity. They also felt that it was sometimes difficult to adhere to the structure of the therapy sessions, and used the plan as more of a guideline to be followed.

All the facilitators found it beneficial having the caregivers/parents involved in the session, however sometimes it was felt that the caregivers did too much of the activity for the children. Two of the facilitators felt that even though they were only supposed to be facilitating the session, they were doing most of the "hands-on" activities with the caregivers watching. All felt that the caregivers were needed in the session to maintain discipline as well as to motivate the children. It was also felt that the caregivers should get more information regarding the actual content of each session prior to each session to allow for smoother running of the sessions.

All the facilitators felt that doing treatment in the group was beneficial to the children and prevented the children from getting too bored and frustrated. It was also a way of motivating the children to participate in the tasks as they saw their other friends doing it as well. It was, however, felt that for future studies, groups should be divided into children of similar

developmental and functional abilities rather than being divided according to their chronological age.

The facilitators felt that two-hour sessions were too long and it was difficult to keep the children's attention for the entire therapy session. It was also felt that by the end of each week the children were becoming fatigued and were less responsive in the group.

The lack of bilateral integration was also a concern for the CIMT facilitators. They said that the children still attempted to use the restrained hand, and would often attempt to perform a task bimanually with the restrained hand and the affected hand. The children would also try to use the restrained hand to secure and stabilize objects. It was also mentioned that during the tactile awareness activities children with the restraint did not have their non-affected hand as a reference for normal sensation.

All of the facilitators felt that having CIMT therapy at RCWMCH was not feasible due to lack of resources and staff, however mention was made that perhaps home-based CIMT could be implemented. This would, however, require careful selection of the children and caregivers who would participate in the CIMT due to compliance and safety concerns. Another suggestion was made to perhaps continue a similar type of programme that was implemented at RCWMCH, but base it in a community centre so parents would not need to travel so far.

4.7 Summary of results

The most pertinent findings were the significant improvement after two weeks of intensive physiotherapy in the hemiplegic children's grasp scores ($p<0.02$) and VMI scores ($p<0.02$). This was also shown by the positive medium effect size of intensive physiotherapy on the grasp scores. This improvement in function was maintained at the six week assessment, even though the children had not received any therapy for a month. There was a significant correlation for all patients receiving intensive physiotherapy between the FMQ score directly post treatment and the change in trunk rotation after treatment ($R=-0.72$, $p<0.01$) There was also a significant correlation between the change of grasp from baseline to two weeks and the changes in

movement time (R=0.78, p=0.005) and the change in movement units for the same time (R=0.67, p=0.035). It was also found that subjects born prematurely had a greater change in grasp, maximum velocity and movement time, than those born at term.

There were no significance differences between the CIMT and the NDT based physiotherapy groups for any of the parameters.

All the parents/caregivers felt that their child's hand function had improved after the two weeks of intensive physiotherapy, however parents of the CIMT subjects did report that their children did get frustrated wearing the CIMT strapping device. The group facilitators felt that group therapy was beneficial, but also felt that CIMT therapy at RCWMCH was not feasible due to lack of resources and staff.

Chapter Five: Discussion

5.1 Patient sample

The main limiting factor of this investigation was that of a small sample size and due to this small sample size and the insufficient power of this research project, definite outcomes of CIMT and or/intensive NDT-based physiotherapy cannot be made.

Despite inviting all the children with hemiplegia managed by the RCWMCH CP clinic (n = 65) to participate in the research study, only twelve children eventually participated in the trial. Twenty-five caregivers agreed to include their children in the study but only 17 of these patients arrived for assessment. There was also a high patient attrition rate, with a large number of children not arriving for the one month follow-up sessions. This high rate of attrition may reflect the underlying social and economic issues within the sectors of the populations using pubic health care facilities. This is an issue that needs to be addressed when planning physiotherapy treatments and future research studies.

It has been noted by RCWMCH therapists, that most patients are unable to regularly attend therapy sessions for a number of reasons including financial, physical and emotional factors (Personal communication, Ms. Parbhoo, 2005). It may be that caregivers were unable to miss two weeks of work in order to bring their child to hospital on a daily basis (and subsidising two weeks salary was not possible from limited research funds). Access and availability of transport from the home to the hospital is often a problem. Caregivers often have other children to care for at home besides their disabled child, and managing two children on public transport is a daunting task. Many families live in informal housing, without electricity and have no access to telephones to rebook appointments. It may also be that the intensity and length of treatment time (i.e. every day for two weeks) was discouraging for some caregivers and they therefore decided not to participate. There may also be a lack of understanding on the part of the caregiver of the importance of general therapy and physiotherapy in the quality of life of her child.

Of the children who did attend the therapy sessions, at least five of the twelve children had acquired cerebral palsy from known causes. The two cases of TBM are worth noting, as they reflect the socioeconomic condition under which these patients live. Problems of poverty and overcrowding predispose this community to Tuberculosis (Krauss-Mars and Lachman, 1992), a preventable disease particularly rife in the Western Cape (Bradshaw et al, 2000).

The fact that so few patients were willing or able to participate in the study suggests that it may not be appropriate to implement similar programmes in the South African context in its current form.

It is apparent that similar problems also face patients in First World environments, where studies have also not been able to enrol sufficient numbers of patients despite being relatively well resourced. The maximum number of patients that have been enrolled in a study is 41 children, with half of these children acting as a control group and only receiving physiotherapy twice a month. The intervention group in that study received physiotherapy at home, which was much more convenient for the family and child and would therefore increase levels of compliance with treatment (Eliasson et al, 2005). Taub, who has published a great deal of research in the use of CIMT, only had a sample of 18 children in the paediatric study that he conducted. However, he made no mention of the reasons for his small sample size (Taub et al, 2004). Most other first world studies consist of patient samples of 7 children or less and once again none of the authors have made any mention as to why they have such small sample sizes (Naylor and Bower, 2005; Karman et al, 2003; Glover et al, 2002). The lack of a sufficient sample size in CIMT is also seen in all areas of research investigating the use of any type of physiotherapy in paediatrics (Boyd et al, 2001; Butler and Darrah, 2001).

5.2 The effect of intensive physiotherapy

The results of this study suggest that a sustained improvement in hand function, visual-motor integration, and fine motor quotient scores in children with hemiplegia followed on two weeks of intensive physiotherapy. However, due to there being no matched control group, these findings need to be interpreted with caution and the definite effects of intensive therapy cannot be made.

5.2.1. The PDFMS

The fine motor quotient (FMQ) has been described as "a composite of the results of the two subtests (grasping and visual motor-integration test) that measure the use of the small muscle systems" (Folio and Fewell, 2000). Some authors argue that one should only quote the Fine Motor Quotient (FMQ) scores when discussing the effects of any treatment on the PDFMS, as this is an age-adjusted score. However, the FMQ score does not detect small changes in that child's hand function and as one needs a large change in raw scores (VMI and grasp scores) to alter the FMQ score. Therefore, in order to detect smaller changes in the hand function, it was decided to analyse the raw grasp and VMI scores of the children.

The grasping subtest measures the child's ability to use his hands, beginning with the ability to hold an object with one hand and progresses to activities that require controlled individual finger action. The Visual Motor Integration measures "the child's visual perceptual skills to perform eye-hand co-ordination tasks, such as reaching and grasping for an object, building with blocks and copying designs" (Folio and Fewell, 2000). The grasp and VMI raw scores are age-sensitive, but in a child over the age of two and a half years hand function starts to become more mature and over a six-week period any changes recorded are unlikely to be due to a normal development (Case-Smith, 2001). This is supported by the fact that although a difference was detected during the treatment phase, no improvement was detected after cessation of active therapy.

There was a highly significant change in raw grasp after two weeks of intensive physiotherapy when combining both patient groups ($p<0.02$), and this improvement was maintained at the one-

month follow-up assessment. This finding was also re-enforced by the positive small effect size of intensive physiotherapy on the change in grasp over two weeks. There was also a significant increase in the VMI score ($p<0.02$), and this improvement was maintained after one month of no therapy ($p = 0.03$).

The improvement in the grasp scores shows that, as a result of the study intervention, the children had improved their ability to grasp objects (such as cubes and small objects) and had better in-hand manipulation (such as being to crumple paper and holding and positioning a pen for drawing). The improvement in the VMI shows that the children had improved in functional activities such as placing shapes in the correct holes, turning pages of a book, placing a spoon correctly in a cup and stirring and building block towers. Therefore this increase in scores should translate to better hand function in every day activities at home and at crèche.

When combining patient groups there was no change in FMQ between the baseline and two week assessments ($p = 0.31$), however there was an improvement in FMQ between the baseline assessment and the one month follow up assessment which approached significance ($p = 0.06$). This may possibly be due to some parents continuing therapy at home after the two weeks of therapy, even though they were not specifically asked to do so for purposes of this study.

The increases of the children's VMI and grasp raw scores after two weeks of therapy, and the maintenance of this improvement for a further four weeks of no therapy is similar to the findings of Knox and Evans (2002), Bower et al (1996) and Bower and McLellan (1992). All these studies noted that there was a maintenance in the improvement of function after an intensive, more frequent, course of therapy (Knox and Evans, 2002; Bower et al, 1996; Bower and McLellan, 1992). Bower et al (1996) similarly demonstrated that children demonstrated improvement in their gross motor function during therapy (assessed with the Gross Motor Function Measure) and maintained this improvement over a period of time, as has been shown in this study. This result is positive, as it suggests that children might maintain their improved function after an intensive period of therapy. It is not known for how long this improvement is maintained without intervention, and this warrants further research.

5.2.2. The Kinematic data

The Vicon instrument was used to assess the reaching movement of the children before and after treatment. All possible attempts were made to standardize the reaching movement for the children. Some practical problems arose when attempting to conduct the assessments. Firstly, some children became distracted during the reaching movement and took a long time to reach for the marshmallow and therefore their movement unit was not as short as would be expected. Secondly, the data collection was sometimes delayed as the children did not respond immediately to the command to "go". As a result the data collector had to try and predict the beginning of the movement by observation. Thirdly, a number of children did not place the marshmallow into the bowl as directed, but took the marshmallow directly to their mouths. Due to this, movement time was calculated as the time that the child took to reach the object, and the maximum range of elbow extension was taken at the point where the child reached the marshmallow and not when placing the marshmallow into the bowl. Due to so many confounding factors, it is impossible to suggest that one group faired better than the other group with their Vicon results. However, there are a few results that are worth mentioning.

Intensive physiotherapy had a positive effect on the change of movement units over the two weeks. This is line with other research that showed a decrease in movement units after only five days of therapy (Fetters and Kluzik, 1996). This indicates that there was an overall improvement in the smoothness and fluency of reach for the children in the study. A reason for this improved smoothness in reaching could be due to the suggestions presented by Volman et al (2002) in a study investigating the effect of task content on reaching in children with cerebral palsy. These suggestions were that smoother movement (fewer movement units) might reflect changes in the degree to which the movements are self-organized and executed in accordance with the dynamic systems model theory.

5.2.3. Correlations between the data sets

There was a significant correlation between the FMQ score directly post treatment and the change in trunk rotation after treatment, with improved function correlating with a decrease in trunk rotation ($p<0.01$, $R=-0.72$). There was also a significant correlation between the change of grasp from baseline to two weeks and the changes in movement time and the change in movement units for the same time. These significant correlations may imply that as hand and arm function improves, it allows increased accuracy of hand placement near an object during reaching with the upper limb. Therefore, fewer compensatory strategies, such as those described by Cirstea and Levin (2000) and Van Thiel and Steenbergen (2001), are needed in order to reach for the object – causing a decrease in trunk rotation.

5.2.4. Possible explanations for improvement

Suggestions as to why an overall improvement occurred are numerous. It can perhaps be suggested that the children used implicit motor learning – which allows the child to improve or gain a skill through practice, without consciously recollecting which areas of the performance improved (Boyd and Weinstein, 2003). This use of implicit motor learning may have led to them learning new hand function skills which they were still able to use a month after therapy. Speculating even further, perhaps this change in motor behaviour was also due to cortical reorganization that might have occurred due to the intensive physiotherapy (Liepert et al, 2000).

The children's improvement may also be due to non-neural factors such as improved strength of the triceps and/or lengthening of the biceps muscle. It is most likely that an improvement in both non-neural and neural factors contributed to the functional improvement in the subjects (Carrey and Burghardt, 1993)

5.3 Implications of findings regarding a short period of intensive treatment in the South African context

This research has shown that intensive group therapy may cause a functional improvement in the hand and upper limb function in children with hemiplegia and that this improvement is maintained after one month of no therapy. It has also shown that group therapy is an effective method of therapy delivery to patients.

This leads one to suggest that intensive group therapy could be implemented more successfully in a community setting, local to the patients, where a community physiotherapist could facilitate group physiotherapy sessions for a short intense period every few months. During the sessions the caregivers would take more responsibility in the handling and mobilizing of their children, hopefully leading to a greater sense of empowerment for the parent or caregiver. Because these sessions would be run in a community setting, the caregiver would not have to spend large amounts of money on transport and if necessary would find it easier to a find another community resident to accompany the child to therapy if the caregiver was unable to attend. This type of group therapy would also decrease the staffing and resourcing costs for the provincial government. These community-based rehabilitation projects have been shown to be effective in rural Zimbabwe have been shown to be effective in reaching people who have not been in contact with rehabilitation services before (Finkenflugel, 1991b). In Zimbabwe, the community-rehabilitation worker, works at the level of the community to address the needs of disabled people and these workers are family- and community- orientated (Finkenflugel, 1991a).

Many children in South Africa who attend government hospitals live in rural areas or poor socio-economic areas[6]. The number of therapists in these areas is inadequate. Admittance of these children to rural hospitals for short intensive periods of treatment might be justified by the findings of this study.

[6] Taken from the Unicef website – www.unicef.org/infobycountryside/southafrica

5.4 Difference between CIMT groups and NDT based physiotherapy groups

At the time of writing this discussion, ten papers had been published internationally regarding the use of CIMT in children with hemiplegia. The largest sample size of any of these studies was 41, in a study in which the 21 children in the intervention group were restrained for two hours a day and were given tasks that involved motivating the child to use their hemiplegic hand and repetition of movement over a period of two months (Eliasson et al, 2005). Willis et al (2002) performed a cross-over study of 25 children who had their upper limbs restrained in a plaster cast for 21 days without any other form of therapy.

Studies similar to the research that was conducted in this dissertation, with children receiving intense therapy daily for two weeks, also described small sample sizes, from between seven (Karman et al, 2003) and eighteen children (Taub et al, 2004) (Figure 11). All the other papers published in this regard ranged from descriptions of three children (Charles et al, 2001) to case studies of one child (Crocker et al, 1997). Previous studies were all conducted in First World countries, with the associated benefits of physical and financial resources, and different social issues than those of South African families. When one considers the barriers to this research posed by its third world setting, it is important to note that this study actually constitutes the fourth largest sample size of all the published literature for paediatric CIMT studies (Figure 11).

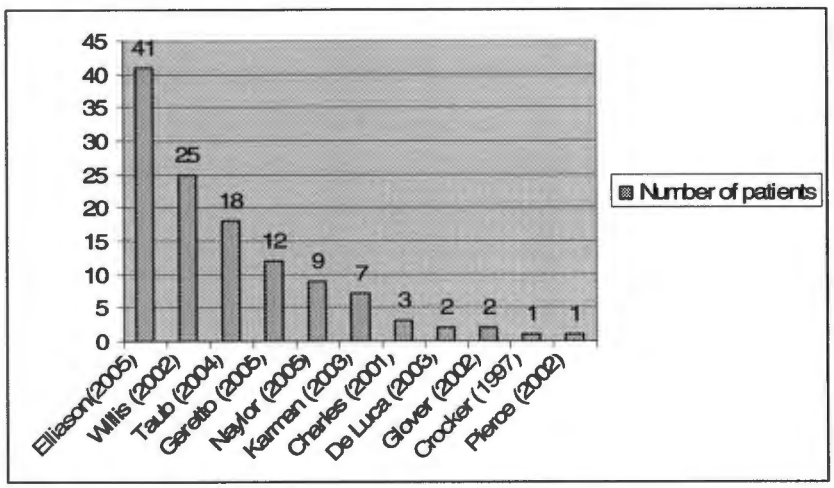


Figure 10: Comparison of subject sample sizes in all CIMT studies (including this research)

There were no significant differences in any of the PDFMS scores (FMQ scores, raw grasp or VMI scores) between the CIMT and the NDT based physiotherapy groups prior to treatment, at two weeks or at the one month post-treatment assessment.

The raw grasp scores in both CIMT and NDT based physiotherapy groups improved after two weeks of treatment, however there appeared to be no additional benefit (on the PDFMS outcome measure) of using group CIMT above group NDT based physiotherapy ($p=0.12$). Fetters and Kluzik (1996) also reported that even though there was no significant difference between two groups of children (one NDT and one practicing reaching) after five days in their study, there was an overall main effect.

A comparison of the results of paediatric, randomized, controlled CIMT studies was made using all studies employing the PDFMS (Table 11). Only one other study was found that fitted these requirements (Willis et al, 2002). This study did not employ any shaping sessions and required the children to wear the restraint 24 hours a day. Willis et al (2002) showed different results to that of the present study.

The present study showed that there was no significant difference between the NDT based physiotherapy and CIMT, with both groups receiving the same amount of therapy time. However, Willis found in their cross-over study that although both the control and treatment groups improved over three weeks, there was a significant difference between the children who were casted ($n=12$) and the control group ($n=13$), with greater improvement occurring in the treatment group. The children were then given a six month period of their regular therapy and then the children that who were previously on the control group where then allocated with a cast a visa versa. The control group ($n=10$) were casted for three weeks, with the treatment group receiving no extra intervention. The control group children made a significant improvement in their hand function, however no mention was made of the difference between the control and treatment group at this period. Only 7 treatment and 10 control patients arrived back after six months, but Willis et al did not suggest any reasons for the lack of compliance in this area.

These difference in outcomes may be due to a difference in age groups between the two studies, with Willis et al (2002) having an age group of one to eight years and the present study of two to five years. In Willis's (2002) study, during both stages of the cross-over study, the children who were not casted received no extra intervention, whilst the children in the CIMT group had their unaffected limb placed in a plaster cast for one month. This also varies from the present study, where both groups of children received equal amounts of therapy time.

Table 12: Randomized controlled CIMT using PDFMS Assessments

Author	**No. of subjects**	**Hours of "therapy" per day**	**Hours restrained per day**	**Days**	**Control Group**	**CIMT effect ($p<0.05$)**
Willis (2002)	22	None	24 hours	21 days	Y	+
Present study	12	2 hours	2 hours	10 days	Y	o

In this research study there were no significant differences between the two groups for elbow range, trunk rotation, movement time, movement units, peak velocity or the ratio of the first movement unit to the total movement time.

The NDT based physiotherapy group showed a non-significant improvement in the mean elbow range of motion (from 117.24 to 125.28 degrees) and a decrease in trunk rotation following two weeks of physiotherapy, which is in line with other studies (Kluzik et al 1990, Van Thiel and Steenbergen, 2001, Cirstea and Levin, 2000), as well as having a general mean decrease in movement time. The decrease in movement time is also consistent with current literature (Kluzik et al, 1990). These results are promising as children with hemiplegia tend to reach with flexion of the elbow, and compensate for this by rotating the trunk towards the object. The changes in elbow and trunk range of movement show an improvement in the functional quality of movement after the therapy, indicating that patients did not need to compensate as much with trunk rotation in order to achieve a functional goal during reaching.

The CIMT group showed a slight, non significant increase in trunk rotation, but also increased their elbow extension range of movement, with a decrease in movement time. These results may be due to technical or measurement problems, and the small sample size.

There therefore appears to be no discernible benefit of using CIMT over NDT based physiotherapy. However, this statement is made with caution considering the small sample size and lack of sufficient power of this study.

5.5 Predictive factors

Subjects born prematurely had a significantly greater change in grasp, maximum velocity and movement time, than those born at term. It is difficult to understand the reasons for this. Research has shown that infants who sustained a brain injury late in the third trimester (which result in cortico-subcortical lesions), have decreased hand function, compared with those infants who sustained injuries in the early stage of the third trimester (which is associated with periventricular lesions and periventricular haemorrhages) (Staudt et al, 2004). In this research study, where CT scans results are available, most of preterm children had periventricular lesions and ventricular haemorrhages, which might be a reason that the preterm subjects showed a greater change than term subjects, however this is only assumption, which requires further research.

To the author's knowledge, the effect of gestational age on the change in grasp has not been investigated in any previous CIMT studies (Eliasson et al, 2005; Taub et al, 2004 and Willis et al, 2002) or in other studies investigating the use of intensive physiotherapy on children with cerebral palsy. Eliasson et al (2005) suggested from their study that older children improved more than younger children. However, in a study comparing the kinematic quality of reaching movements in preterm infants without cerebral palsy, preterm infants showed a more advanced reaching pattern than full term babies during the study period of the first 6 months of life (Fallang, Suagstad, Grograad and Hadders-Algra, 2003).

Subjects with idiopathic CP showed a greater change in elbow ROM than those who acquired CP postnatally. To the author's knowledge, no other studies investigating the use of physiotherapy, CIMT or kinematic analysis in paediatrics have done any further investigations into this and further research is needed in this area.

No other significant effects were found between side of hemiplegia and acquired or congenital hemiplegia on the PDFMS and kinematic analysis data. This might be due to the small sample size. However, the initial motor performance of the individual patient was not assessed as a predictive outcome.

5. 6 Perceptions about CIMT use

Very little research has been conducted investigating how parents perceive the use of CIMT in their children. De Luca et al (2003) discussed how parents felt about the improvement in their child's hand, but very little was mentioned about their child's level of frustration or how they felt regarding the length of time of the shaping sessions.

A few interesting themes emerged from the discussion and questionnaire.

Participation: There was a discrepancy noted between the parents who reported that their children participated well in the sessions and the physiotherapists who felt that a number of patients did not participate well.

Frustration and tiredness: Frustration and tiredness were noted frequently by four of the five parents whose children wore the CIMT strapping devices. Most of the parents, and the physiotherapists, stated that the children became tired towards the end of two hours and also were very fatigued by the end of every week – which would suggest that the level of the child's participation in the activity would also decrease. It is interesting to note that very few papers have mentioned issues of frustration and fatigue in children due to wearing CIMT with intense therapy. It also draws into question the level of participation in other studies where children were restrained in Plaster of Paris continuously for three weeks (Willis et al, 2002).

Feasibility: This research bought to light not only the lack of feasibility of Taub's (Taub et al, 1993) CIMT protocol in the South African context (i.e. individual treatment, 90% waking hours, 6 hours shaping per day), but also the underlying frustration that accompanies this type of practice. The decision not to implement the same CIMT protocol as Taub's (by not restraining the children at home and only providing two hours of shaping a day) was shown to have some merit as parents/caregivers noted that most of the children became tired and frustrated after just two hours of CIMT. It is felt that serious ethical considerations need to be examined in studies such as Willis et al (2002), who placed Plaster of Paris on a children's hand for one month and no mention was made of the child and parent's emotional status regarding this.

Group therapy: Both parents and physiotherapists stressed the importance of group therapy for the child. The children were said to have enjoyed the group therapy sessions and some formed friendships with other children in the group. It was also suggested that the children participated better in the group and that the group prevented the children from becoming too bored with the activities and often encouraged the children to attempt to do better in order to compete against one another. This is an interesting point that has been raised, as Taub et al (2004) has argued against the use of group therapy in CIMT saying that it impedes the shaping process. In this setting of the current study, however, it can be suggested that group work may have improved the participation of the children during certain tasks, a view supported by other authors (van der Lee et al, 1999).

Bimanual activities: The physiotherapists also discussed the lack of bimanual activities whilst wearing the CIMT. Children with hemiplegia already have problems bringing the hands to the midline and using both hands in bilateral activities (Bobath and Bobath, 1975). These difficulties were emphasized even further when wearing the CIMT mitt, as some activities such as dressing require both hands to complete the task and due to the mitt this was not possible to achieve. In order to compensate for the lack of bilateral hand activities, often children would use the mitted hand to secure an object and use the affected hand to attempt the fine motor task required. Even though this has shown to help the fine hand motor function of the study children; in real life settings, it would be more functional for the children to be taught how to stabilize

with their affected and use their non-affected hand to do most fine motor tasks – as this will allow for greater quality and efficiency of movement. This was further demonstrated during a one month follow up assessment with a child, who wanted to only use the affected hand in all activities at home and at school. It was pleasing to see that he was starting to attempt to use the affected hand, however it was distressing to note the increased effort required to perform every day functional activities due to not wanting to do any bimanual activities. It was also mentioned that it is important for children with hemiplegia to use their hands in bilateral integration activities, in order to overcome any visual and motor perceptual problems that might arise. Unfortunately, CIMT does not allow for this.

Sensory issues: The physiotherapists mentioned that some children appeared to have sensory impairments in their affected hand. This has also been described by Sterr et al (2002b), Gordan and Duff (1999) and Steenbergen et al (1998). During CIMT, the non-affected hand is strapped and the children do not have a "normal" reference in which to compare the sensory input which they are receiving with their affected hand.

Hospital versus home CIMT: It was felt that it was not feasible to conduct such intensive CIMT sessions at RCWMCH due to parents being unable to afford the transport to the hospital, the huge burden on the staff required to facilitate the CIMT sessions and the lack of resources that the hospital has to admit the patients. However, it was felt that CIMT might be attempted at home provided that the parent was sufficiently responsible and could ensure the child would be safe and compliant to therapy. Other studies have conducted CIMT in the patient's home with a physiotherapist in attendance (Crocker et al, 1997). This would not be possible under the current staffing conditions in RCWMCH. Another possibility is to train a community worker to conduct group CIMT sessions in a community centre.

It was discussed with the facilitators that careful selection needed to take place before commencing a CIMT programme with children. Criteria for children to participate in the CIMT would be those children who are known to be compliant with physiotherapy and who have a good understanding (for their age level) of the reasons underlying the CIMT. It is also felt that children need to have some active movement in the affected hand in order for them to take part

in the tasks, otherwise this would be extremely frustrating for the child. This has also been mentioned in previous studies (Taub et al, 2004).

5.7 The feasibility of implementing CIMT in the South African context

This research suggested that it is not feasible to implement CIMT in this the South African context in its current form, and this may apply to other developing countries. There are many aspects that make CIMT therapy as described by Taub et al (2004) unrealistic in a resource poor setting. Firstly, due to poverty and poor social circumstances in the developing world, including peri-urban Cape Town, people cannot afford the daily cost of transport and the loss of a day's earning to come into the hospital. It can be said that this has not changed since 1978 when Arens first described the situation (Arens et al, 1978). This leads to poor patient participation and compliance in the CIMT programme – as was seen in this study despite having transport costs paid by the researcher. Secondly, the lack of physical and financial resources in the provincial hospitals in South Africa, specifically insufficient staffing levels, make it impossible to run these intensive types of programmes.

Even though this intense type of CIMT is not feasible, it would be interesting to determine if a programme similar to the one that Eliasson et al (2005) used, where the children wore a mitt for two hours everyday in a home or crèche situation, would be beneficial in this community. If CIMT were proven to be superior to a typical physiotherapy programme in this population, it would be worth investigating how long the maintenance of function lasted for children after the CIMT. It may be possible to conduct short, intense CIMT shaping programmes only once or twice a year instead of regular monthly therapy.

5.8 Limitations

The limitations of this study are as follows:

- The small patient sample and lack of sufficient power, which had a large effect on the interpretation of the results;
- The results of this study cannot be extrapolated to any other group due to the small size;
- Trunk and elbow range of movement were not assessed at one month post-treatment, due to practical constraints;
- Behaviour fluctuations in children during assessments may have affected the results. For example, during the first assessment the child may have co-operated well, but on subsequent assessments was distracted or uncooperative. Thus this child's true potential may not have been reflected. However, these behaviour fluctuations would not have been as much of a concern if there was a larger sample size;
- Follow-up was only performed after one month. It would have been useful to conduct a further assessment at, for example, two months post therapy to determine the permanence of the improvement seen after the therapy;
- Fatigue of study participants towards the latter part of the two-hour sessions meant that they may not have participated optimally towards the end of the session; and
- The questionnaire presented to the caregivers was not validated; and the "traditional" CIMT outline (e.g. 90% waking hours, 6 hours shaping per day) was not tested due to resource constraints and ethical issues. Therefore it is not possible to directly compare any of these results with those of other studies who underwent the traditional CIMT protocol.
- Only one site was used for the study. If more than one site had been used, this would have possibly allowed for a greater sample size.
- A further leaflet should have been provided to individual physiotherapists working with the caregivers and patients at the Red Cross Children's Hospital. This would have helped to aid discussion regarding the research project between the physiotherapist and caregiver, and possibly increased the sample size.

- Follow up letters were not sent to patients who did not arrive for their initial assessment and this may also have contributed to the poor response and poor sample size of the study.

Chapter Six: Conclusion and recommendations

6.1 Conclusion

The study suggested that there was a statistically and clinically significant improvement in raw grasp scores and visual-motor integration scores after intensive group therapy over a two week period, and that this improvement in function was maintained for one month. The clinical significance of this improvement was also suggested by parental reports of improved function in every day activities such as grooming and dressing, which helped to decrease the burden on the parent. However, due to there being no matched control group, these findings need to be interpreted with caution and the definite effects of intensive therapy cannot be made.

Due to the small size of this study, it was not possible to determine whether group CIMT or NDT based physiotherapy was more effective in improving the hand function of children with hemiplegia.

It has been shown that CIMT therapy, as described in this study, is generally inaccessible to a poor population who cannot afford the cost of transport or daily therapy, as well as the lack of resources at government institutions which are needed to carry out this therapy. CIMT in its current form could, perhaps, be implemented in private hospitals where patients are wealthier and more resources are available.

6.2 Recommendations

Definitive recommendations regarding the implementation of CIMT and/or intensive NDT based physiotherapy programmes cannot be made until a study of sufficient power has been conducted in the same population group.

However, based on both the quantitative results and the feedback from the physiotherapists regarding CIMT, it is not recommended that that this form of treatment be introduced as a routine form of treatment in the South African context. This research can be viewed as a pilot study for a larger randomised controlled trial, of at least forty patients, to investigate the effects and efficacy of CIMT. In order to achieve sufficient patient numbers, it is recommended that a multi-centre study be initiated, including other centres throughout South Africa who have NDT-trained physiotherapists. A cross-over study design may be necessary to further strengthen the investigation. Another research trial could also investigate the compliance of caregivers and children in wearing the CIMT mitt at home and participating in a structured home therapy programme, instead of coming into the hospital everyday for treatment.

It is an encouraging finding that, despite the small sample size, a two week period of intensive physiotherapy within a group setting was found to significantly improve function. In the South African context of limited resources, particularly in rural areas, an intermittent two week intensive treatment period might be more feasible than regular weekly therapy. This is a model of service delivery which needs further investigation as the results of this preliminary study indicate that this might be effective. Another possible model that warrants further research is that of community-based group therapy programmes, making use of a central public facility (e.g. church or school hall) as this would be more accessible to the community.

References

Altman D (1991). Practical statistics for medical research. 2nd edition. London: Chapman and Hall. p 456.

Analyse-It (Version 1.71, © Analyse-It Software Ltd 2001)

Arens, L, Molteno C, Marshall S, Robertson W, Rabkin J. (1978) Cerebral Palsy in Cape Town. A comparative 12-year retrospective study. South African Medical Journal. March: 319-324

Arens L and Molteno C. (1989) A comparative study of postnatally-acquired cerebral palsy in Cape Town. Developmental Medicine and Child Neurology Vol 31: 246-254

Barry M. (1996) Physical therapy interventions for patients with movement disorders due to cerebral palsy. Journal of Child Neurology. Vol 11 (Suppl 1): S51-60

Bly L. (1991) A historical and current view of the basis of NDT. Pediatric Physical Therapy Vol 3:131-135

Bly L. (1994) Motor Skills Acquisition in the First Year. Texas: Therapy Skill Builders.

Bobath B and Bobath K. (1975) Motor Development in the different types of cerebral palsy. Boston: Butterworth-Heinemann Ltd pp 17, 43-56

Bonifer N, Anderson K. (2003) Application of constraint-induced movement therapy for an individual with severe chronic upper-extremity hemiplegia. Physical Therapy. Vol 83:384-398

Bower E, McLellan D. (1992) Effect of increased exposure to physiotherapy on skill acquisition of children with cerebral palsy. Developmental Medicine and Child Neurology. Vol 34:25-39

Bower E, McLellan D, Arney J, Campbell M. (1996) A randomized controlled trial of different intensities of physiotherapy and different goal-setting procedures in 44 children with cerebral palsy. Developmental Medicine and Child Neurology. Vol 38:226-237

Boyd L, Weinstein C (2003). Impact of explicit information on implicit motor-sequence learning following Middle Cerebral Artery stroke. Physical Therapy. Vol 83 (11): 976-989.

Boyd R, Pliatsios V, Starr R, Wolfe R, Graham H. (2000) Biomechanical transformation of the gastrocs-soleus muscle with botulinum toxin A in children with cerebral palsy. Developmental Medicine and Child Neurology. Vol 42:32-41

Boyd R, Morris M, Graham H. (2001) Management of upper limb dysfunction in children with cerebral palsy: a systematic review. European Journal of Neurology. Vol 8 (suppl 5):150-166

Bradshaw D, Groenewald P, Laubscher R, Nannan N, Nojilana B, Pieterse D, Schneider M et al. (2003) Initial burden of disease estimates for South Africa 2000. South African Medical Journal. Vol 93(9): 682-688

Brown G, Burns S (2001). The Efficacy of Neurodevelopmental Treatment in Paediatrics: a Systemic Review. British Journal of Occupational Therapy Vol 64(5): 285-244

Butler C, Darrah J (2001a) AACPM evidence report: Effects of Neurodevelopmental (NDT) for Cerebral Palsy. www.aacpdm.org: American Academy for Cerebral Palsy and Developmental Medicine.

Butler C, Darrah J. (2001b) Effects of Neurodevelopmental treatment (NDT) for cerebral palsy: an AACPDM evidence report. Developmental Medicine and Child Neurology. Vol 43: 778-790

Campbell S. (1991) Clinics in Physical Therapy - Pediatric Neurologic Physical Therapy. New York: Churchill Livingstone, pp 301.

Cammisa K, Calabrese D, Myers M, Tupper G, Moser K, Crawford K, Pope L et al. (1995) NDT theory has been updated: letter to the editor. The American Journal of Occupational Therapy. Vol 49 (2): 176

Carey J, Burghardt T. (1993) Movement dysfunction following central nervous system lesions: A problem of neurologic or muscular impairment? Physical Therapy. Vol 73 (8): 538-545.

Case-Smith J. (2001) Occupational Therapy for Children: 4th edition. St Louis: Mosby Inc.

Case-Smith J. (1994) The relationship among sensori-motor components, fine motor skill, and functional performance in preschool children. The Amercian Journal of Occupational Therapy. Vol 49(7):645-652

Charles J, Lavinder G, Gordan A. (2001) Effects of Constraint-Induced Therapy on hand function in children with hemiplegic cerebral palsy. Pediatric Physical Therapy. Vol 13:68-76

Cirstea M, Levin M. (2000) Compensatory strategies for reaching in stroke. Brain. 123: 940-953

Cohen J (1988) Statistical power for the behavioural sciences (2nd edition). Hillsdale, NJ. Lawrence Earlbaum Associates (taken from the website: www.web.uccs.edu/lbecker)

Crocker M, Mackay-Lyons M, McDonnell E. (1997) Forced use of the upper extremity in cerebral palsy: a single-design. The American Journal of Occupational Therapy. Vol 51:824-833.

Curzon (1987) in Penso (1987) Occupational Thearpy for the children with disabilities. LondonCroom Helm Ltd, pp 22-29

Davies PM. (1994) Steps to follow: A guide to the treatment of adult hemiplegia. Berlin: Springer-Verlag. p 3

De Gangi G. (1994) Examining the efficacy of short-term NDT intervention using a case study design: Part 1. Physical and Occupational Therapy. Vol 14 (1):71-87

De Luca S, Echols K, Ramey S, Taub E. (2003). Pediatric Constraint-Induced Movement Therapy for a Young Child with Cerebral Palsy: Two episodes of care. Physical Therapy. Vol 83 (11):1003-1013

Dromerick. A. (2003) Guest Editorial, Journal of Rehabilitation Research and Development. Vol 40, No 1

Dromerick A, Edwards D, Hahn M. (2000) Does the application of constraint-induced movement therapy during acute rehabilitation reduce arm improvement after ischaemic stroke? Stroke. Vol 31: 2984-2988

Eliasson A, Krumlinde-Sundholm L, Shaw K, Wang C (2005). Effects of constraint-induced movement therapy in young children with hemiplegic cerebral palsy: an adapted model. Developmental Medicine and Child Neurology. Vol 47: 266-275

Erhardt R. (1994) Developmental Hand Dysfunction: Theory, assessment and treatment. Texas: Therapy Skill Builders

Ernst E. (1990) A review of stroke rehabilitation and physiotherapy. Stroke. Vol 21(7):1080-1085

Exner C (1989) in Pratt and Allan's Occupational Therapy for Children: 2nd edition. St Louis: The C.V Mosby Company

Exner C (2001) in Case-Smith's Occupational Therapy for Children: 4th edition. St Louis: Mosby, Inc. p 289

Fallang B, Suagstad O, Grograad J, Hadders-Algra M. (2003) Kinematic quality of reaching

movements in preterm infants. Pediatric Research. Vol 53 (5): 836-842

Farmer S, Harrison L, Ingram D, Stephens J. (1991) Plasticity of central motor pathways in children with hemiplegic cerebral palsy. Neurology. Vol 41:1505-1510

Fetters L, Kluzik J. (1996) The effects of Neurodevelopmental Treatment versus practice on the reaching of children with spastic cerebral palsy. Physical Therapy, Vol 76 (4): 346-358

Finkenfungal HJ (1991a). Identifying people in need of rehabilitation in rural Zimbabwe. Central African Journal of Medicine. Vol 37(4):105-10

Finkenfungal HJ (1991b) Help for the disabled – in hospital and at home. World Health Forum. Vol 12(3): 325-30

Flegel J, Kolobe T.(2002) Predictive validity of the Test of Infant Motor Performance as measured by the Bruininks-Oseretsky Test of Motor Proficiency school age. Physical Therapy. Vol 82 (8):7

Folio M and Fewell R. (2000) Peabody Developmental Motor Scales, 2nd edition. Texas: Pro-ed Publishers

Fonseca S, Holt K, Fetters L, Saltzman E. (2004) Dynamic resources used in ambulation by children with spastic hemiplegic cerebral palsy: relationship to kinematics, energetics and asymmetries. Physical Therapy. Vol 84(4): 344-358

Galligan A. (2000) The place where we live: The discovery of play through creative play experience. Journal of child and adolescent psychiatric nursing Vol 13 (4):169-176

Gebhard A, Ottenbacher J, Lane S. (1994) Interrater reliability of the Peabody Developmental Motor Scale: Fine Motor Scale. The American Journal of Occupational Therapy. Vol 48 :976-981

Gesell A. (1976) The first five years of life. A guide to the study of the pre-school child. Berlin: Methuen and Co. Ltd, pp 47, 251-253.

Gillot A, Holder-Walls A, Kurtz J, Varley N. (2003) Perceptions of two survivors of stroke who participated in Constraint-Induced Movement Therapy home programs. The American Journal of Occupational Therapy. Vol 57:168-176

Glover J, Mateer C, Yoell C, Speed S. (2002) The effectiveness of constraint induced movement therapy in two young children with hemiplegia. Pediatric Rehabilitation. Vol 5(3):125-131

Goldstein M (2004) The Treatment of Cerebral Palsy: What we know, what we don't know. The Journal of Pediatrics. Vol 145: S42-S46

Gordan A, Charles J, Wolf S. (2005) Methods of Constraint-Induced Movement therapy for children with hemiplegic cerebral palsy: Development of a child-friendly intervention for improving upper-extremity function. Archives of Physical and Medical Rehabilitation. Vol 86: 837-843

Gordan A, Duff S. (1999) Relation between clinical measures and fine manipulative control in children with hemiplegic cerebral palsy. Developmental Medicine and Child Neurology Vol 41:586-591

Griffiths M, Clegg M (1988). Cerebral Palsy: Problems and Practice. London, Souvenior Press (Educational and Academic)Ltd.

Gulliani CA. (1991) Theories of motor control: New concepts for physical therapy. In: Contempary Management of Motor Problems. Proceedings of the II STEP Conference, Alexandria, Virginia. The Foundation for Physical Therapy, 1991, 31. (Taken from Louise Rut-La Pitz's lecture (2004) "Motor Control, Motor Learning and Constraint-Induced Movement Therapy in the treatment of the hemiplegic arm")

Hartley-Amien F, Stephenson M, Stephenson V, Van den Berg H and Jelsma J. (2005) The validity of the Peabody Scale Norms in a sample of South African Xhosa speaking children. BSc Physiotherapy undergraduate research project, University of Cape Town.

Hart H. (2005) Can constraint therapy be developmentally appropriate and child-friendly? Developmental Medicine and Child Neurology. Vol 47:363

Hinderer K, Richardson P, Atwater S. (1989) Clinical implications of the Peabody Developmental Motor Scales: A constructive review. Physical Therapy and Occupational Therapy in Pediatrics. Vol 9(2): 81-106.

Howe T and Oldham J. (1995) Measuring muscle tone and movement. Nursing Standard. Vol 9(39): 25-29

Hlustik P, Mayer M. (2006) Paretic Hand in Stroke: From Motor Control Plasticity Research to Rehabilitation. Cognitive Behaviour Neurology. Vol 19:34-40

Huskisson N (1998) The avalanche of children requiring social services in the Western Cape. South African Medical Journal. Vol 88 (4): 437-439.

International Workshop on Definition and Classification of Cerebral Palsy, United Cerebral Palsy Research (2004), Maryland.

Jeffree D, McConkey R and Hewson S (1979) Let me play. London: Souvenir Press (E and A) Ltd.

Karman N, Maryles J, Baker R, Simpser E, Berger-Gross P. (2003) Constraint-Induced Movement Therapy for children with hemiplegia with acquired brain injuries. Journal of Head

Trauma Rehabilitation. Vol 18 (3): 259-267

Kluzik J, Fetters L, Coryell J. (1990) Quantification of Control: A preliminary study of the effects of Neurodevelopmental treatment on reaching in children with spastic cerebral palsy. Physical Therapy. Vol 70 (2): 65-78

Knopp B, Kunkel A, Flor H, Platz T, Rose U, Mauritz K-H, Gresser K, McCulloch K, Taub E. (1997) The Arm Motor Ability Test: Reliability, validity, and sensitivity to change of an instrument for assessing disabilities in activities of daily living. Archives of Physical Archives of Physical Medicine and Rehabilitation, Vol 78:615-620.

Kraus-Mars A and Lachman P (1992) Social factors associated with tuberculosis meningitis. South African Medical Medicine and Rehabilitation. Vol 78:615-620.

Knox S (1997) in Parham and Fazio's Play in Occupational Therapy for Children:. St. Louis: Mosby Publishers.

Knox V and Evans M. (2002) Evaluation of the functional effects of a course of Bobath therapy in children with cerebral palsy: a preliminary study. Developmental Medicine and Child Neurology. Vol 44: 447-460

Kolobe T, Palisano R, Stratford P (1998) Comparison of two outcome measures for infants with cerebral palsy and infants with motor delays. Physical Therapy. Vol 78 (10): 1062-1072

Koman L, Smith B, Shilt S. (2004) Cerebral Palsy. The Lancet. Vol 36: 1619-1641

Kunkel A, Knopp B, Muller G, Villringer K, Villringer A, Taub E, Flor H. (1999) Constraint-induced movement therapy for motor recovery in chronic stroke patients. Archives of Physical Medicine and Rehabilitation. Vol 80: 624-628.

Lanksa MJ, Lanksa DJ, Horwitz SJ and Aram DM. (1991) Presentation, clinical course, and

outcome of childhood stroke. Pediatric Neurology Vol 7(5):333-41

Law M, Cadman D, Rosenbaum P, Walter S, Russel D, DeMatteo C. (1991) Neurodevelopmental therapy and upper-extremity casting for children with cerebral palsy. Developmental Medicine and Child Neurology. Vol 33:379-387

Law M, Russel D, Pollock N, Rosenbaum P, Walter S, King G. (1997) A comparison of intensive Neurodevelopmental Therapy plus casting and a regular occupational therapy program for children with cerebral palsy. Developmental Medicine and Child Neurology. Vol 39:664-670

Levitt S. (1995) Treatment of cerebral palsy and motor delay. 3rd edition. Cambridge: Blackwell Science.

Levy C, Nicholas D, Schmalbrock P, Keller P, Chakeres D. (2001) Functional MRI evidence of cortical reorganization in upper limb stroke hemiplegia treated with Constraint-Induced Movement Therapy. American Journal of Medical Rehabilitation. Vol 80 (1): 4- 12

Liepert J, Miltner WH, Bauder H, Sommer M, Dettmers C, Taub E, Weiller C. (1998) Motor cortex plasticity during Constraint-Induced Movement Therapy in stroke patients. Neuroscience Letters. Vol 250 (1):5-8

Liepert J, Bouder H, Miltner W, Taub E, Weiller C. (2000) Treatment-induced cortical reorganization after stroke in humans. Stroke. Vol 31:1210-1216

Mayston M (2001) The Bobath Concept Today (talk given at CSP Congress, October 2000). www.bobath.org.uk

Mathiowetz V, Haugen J. (1994) Motor Behaviour Research: Implications for therarapeutic approaches to Central Nervous System dysfunction. The American Journal of Occupational Therapy. Vol 48 (8): 733-745.

Mercuri E, Rutherford M, Cowan F, Pennock J, Counsell S, Papadimitiriou M, Azzopardi et al. (1999) Early prognostic indicators of outcome of infants with neonatal cerebral infarction: A clinical, electroencephalogram and magnetic resonance imaging study. Pediatrics. Vol 103:39-46.

Mercuri E,.Barnett A, Rutherford M, Guzzetta A, Haataja L, Cioni G, Cowan F, Dubowitz. (2004) Neonatal cerebral infarction and neuromotor outcome at school age. Pediatrics. Vol 113 (1): 95 – 100.

Miltner W, Wolfgang H, Monika S, Dettmers C, Taub E (1999) Effects of constraint-induced movement therapy on patients with chronic motor deficit after stroke. Stroke. Vol 30:586-592.

Mittal S, Farmer J, Al-Atassi B, Montpetit K, Gervais N, Poulin C, Cantin M et al. (2002) Impact of selective posterior rhizotomy on fine motor skills. Pediatric Neurosurgery. Vol 36:133-141

Morrison C, Metzger P (2001) in Case-Smith's Occupational Therapy for Children: 4th edition. Publishers: Mosby Inc.

Muller R, Rothermel R, Behen M, Muzik O, Chakraborty P, Chugani H (1997). Plasticity of motor organization in children and adults. Neuroreport Vol 8: 3103-3108

Naylor CE, Bower E. (2005) Modified Constraint-Induced Movement Therapy for young children with hemiplegic cerebral palsy: a pilot study. Developmental Medicine and Child Neurology. Vol 47: 365-369

NINDS Workshop on Classification and Definition of Disorders Causing Hypertonia in Childhood, 2001. http://www.ninds.nih.gov/news_and_events/Hypertonia_Meeting_2001.htm

Ottenbacher K, Jannell S. (1993) The results of clinical trials in stroke rehabilitation research. Archives of Neurology. Vol 50:37-44

Oxford concise medical dictionary (1998). New York, Oxford: Oxford University City Press

Page S, Sisto S, Levine P, McGarth R. (2004) Efficacy of modified Constraint-Induced Movement Therapy in chronic stroke: A single-blinded randomized control trail. Archives of Physical Medicine and Rehabilitation. Vol 85:14-18

Page S, Levine P, Sisto S, Bond Q, Johnston M. (2002) Stroke patients and therapists opinions of Constraint-Induced Movement Therapy. Clinical Rehabilitation. Vol 16:55-60

Paneth N, Damiano D, Rosenbaum P, Leviton A, Goldstein M, Bax M. (2004) The classification of cerebral palsy. An International Workshop on Definition and Classification of Cerebral Palsy, Bethesda, Maryland, July 2004.

Parbhoo A. (2004) Personal communication – Head Physiotherapist, Red Cross Children's Hospital.

Pehoski, Henderson, Tickle-Degnen. (1997a) In-hand manipulation in young children: Rotation of an object in the fingers. The American Journal of Occupational Therapy Vol 51 (7):544-552

Pehoski, Henderson, Tickle-Degnen. (1997b) In-hand manipulation in young children: Translation movements. The American Journal of Occupational Therapy Vol 51 (9): 719-728

Penso D. (1987) Occupational Therapy for the children with disabilities. London: Croom Helm Ltd, pp 22-29

Pierce S, Daly K, Gallagher K, Gershkoff A, Schaumberg S. (2002) Constraint-Induced Movement Therapy for a child with hemiplegic cerebral palsy: a case report. Archives of Physical and Medical Rehabilitation. Vol 83:1462-1463

Pratt P and Allan A. (1989) Occupational Therapy for Children: 2nd edition. St Louis: The C.V Mosby Company, pp 235-295, 221

Primeau and Parham (1997) from Parham and Fazio's Play in Occupational Therapy for Children:. St. Louis. Mosby Publishers.

Provost B, Crowe T, McClain C. (2000) Concurrent Validity of the Bayley Scales of Infant Development 2 Motor Scale and the Peabody Developmental Motor Scales in Two-Year-Old Children. Physical and Occupational Therapy in Pediatrics. Vol 20(1): 5 - 18

Reilly (1989) from Pratt and Allan's Occupational Therapy for Children: 2nd edition. St Louis: The C.V Mosby Company.

Riddick B. (1982) Toys and play things for the handicapped child. London: Croom Helm Ltd, pp 95-136

Rumea—Rouquette C, Grandjean H, Cans C, du Mazaubrun C, Verrier A (1997) Prevelance and time trends of disabilities in school age children. International Journal of Epidemiology Vol 26, 137-145.

Russel D, Rosenbaum P, Cadman D, Gowland C, Hardy S, Jarvis S. (1989) The Gross Motor Function Measure: A means to evaluate the effects of physical therapy. Developmental Medicine and Child Neurology. Vol 31: 341-352

Rutz LaPitz (2004) Motor Control, Motor Learning and Constraint-Induced Movement Therapy in the Treatment of the Hemiplegic Arm. (Lecture given at the Tybergerg Campus, South Africa – 2004)

Scholtz C. (2002) Occupational Therapy Neurodevelopmental Therapy Course Notes. (from Basic Neurodevelopmental Therapy Course for Paediatrics – Cape Town, 2002)

Schoeman C. (1990) The epidemiology and outcome of childhood Tuberculosis meningitis: The Pelonomi Hospital Experience. South African Medical Journal. Vol 78:245-247

Sharpo B. (2004) Cerebral Palsy: A reconceptualization of the spectrum. Journal of Pediatrics. Vol 145:S3-S6

Sharky M. (2002) Letter to the editor: Neurodevelopmental treatment for cerebral palsy: is it effective? Developmental Medicine and Child Neurology, Vol 44:430-422

Sheridan M. (1994) From birth to five years: Children's developmental progress. New York. Routledge Publishers.

Siegert R, Lord S. (2004) Constraint-Induced Movement Therapy: time for a little restraint? Clinical Rehabilitation. Vol 18:110-114

Song K, Concha M, Haideri N. (2001) Effects of lower limb torsion on ankle kinematic data during gait analysis. Journal of Pediatric Orthopaedics. Vol 21:792-797

Statistica (Kernel Release 6.1, © StatSoft Inc 1984 – 2003).

Stuadt M, Gerloff C, Grodd W, Holthausen H, Nieman G, Krageloh-Mann I (2004). Reorganization in congenital hemiparesis acquired at different gestational ages. Annuals of Neurology Vol 56:854-863

Steenbergen B, Hulstijn W, Lemmens I, Meulenbroek R. (1998) The timing of prehensile movements in subjects with cerebral palsy. Developmental Medicine and Child Neurology. Vol 40:108-114

Sterr. A, Elbert T, Berthold I, Kobel S. Rockstroh B, Taub E. (2002a) Longer versus shorter daily Constraint-Induced Movement Therapy in chronic hemiparesis: An exploratory study. Archives of Physical and Medical Rehabilitation. Vol 83:1374 – 1377

Sterr A, Freivogel S, Schmalohr D (2002b) Neurobehavioural aspects of recovery: Assessment of the learned nonuse phenomenon in hemiparetic adolescents. Archives of Physical Medicine and Rehabilitation. Vol 83:1726-1731.

Sugden D, Utley A. (1995) Interlimb coupling in children with hemiplegic cerebral palsy. Developmental Medicine and Child Neurology. Vol 37:293-309

Taub E, Miller N, Novack T, Cook E, Flemming W, Nepomuceno M, Connell B, Crago J. (1993) Technique to improve chronic motor deficit after stroke. Archives of Physical Medicine and Rehabilitation. Vol 74:347-354

Taub E, Uswatte G, Pidikiti R. (1999) Constraint-Induced Movement Therapy: a new family of techniques with broad application to physical rehabilitation – a clinical review. Journal of Rehabilitation Research and Development. Vol 36(3):237-257

Taub E. (2000) Constraint-Induced Movement Therapy and massed practice. Stroke. Vol 31 (4): 986-988

Taub E, Uswatte G. (2003) Constraint-Induced Movement Therapy: bridging from the primate laboratory to the stoke rehabilitation laboratory. Journal of Rehabilitative Medicine, Suppl 41:34-40

Taub E, Ramsey S, De Luca S, Echols K.(2004) Efficacy of Constraint-Induced Movement Therapy for children with cerebral palsy with asymmetric motor impairment. Pediatrics. Vol 113:305 – 312

Tecklin, J. (1989) Pediatric Physical Therapy. Publishers: J.B. Lippincott Company, pp 68

Thompson C, Buccimazza S, Webster J, Malan A, Molteno C. (1993) Infants of less than 1250 grams birth weight at Groote Schuur Hospital: Outcome at 1 and 2 years of age. Pediatrics. Vol 91(5):961-968

United Cerebral Palsy Research and Educational Foundation (2004). An International Workshop on Definition and Classification of Cerebral Palsy, 2004. Bethesda, Maryland.

Vaccarino F, Ment L (2004). Injury and repair in developing brain. Arhcives of Disability Child, Fetal and Neonatal Education. Vol 89:190-192

Van der Lee J, Beckerman H, Lankhorst G, Bouter L. (2000) Constraint-induced movement therapy. Physical Therapy, Vol 80(7):711.

Van der Lee, J. Wagenaar R, Lankhorst G, Vagelaar T, Deville W, Bouter L. (1999) Forced use of the upper extremity in chronic stroke patients. Stroke Vol 30:2369-2375

Van Thiel E, Steenbergen B. (2001) Shoulder and hand displacements during hitting, reaching and grasping movements in hemiparetic cerebral palsy. Motor Control. Vol 2:166-182

Vaughan C and O'Malley M (2004). A gait nomogram used with fuzzy clustering to monitor the functional status of children with cerebral palsy. Submitted for publication to Developmental Medicine and Child Neurology in 2004.

Volman J, Wijnroks A, Vermeer A. (2002) Effect of task content on reaching performance in children with spastic hemiparesis. Clinical Rehabilitation. Vol 16:694 -692

Western Cape Cerebral Palsy Assocation – Statistics of Cerebral Palsy Children in the Western Cape, 2003 and 2004.

Willis, J. Morello A, Davie A, Rice J, Bennet J. (2002) Forced use in treatment of childhood hemiparesis. Pediatrics. Vol 110:94-96

WINKS statistical data analysis (5th edition, © Texasoft Inc)

Wren T, Rethlefsen S ,Kay R. (2005) Prevalence of Specific Gait Abnormalities in Children With Cerebral Palsy: Influence of Cerebral Palsy Subtype, Age, and Previous Surgery. Journal of Paediatric Orthopaedics Vol 25:79-83

Wood E, Rosenbaum P. (2000) The Gross Motor Function System for Cerebral Palsy: a study of reliability and stability over time. Developmental Medicine and Child Neurology. Vol 42: 292-296.

Wu C, Trombly C, Lin K, Degnen-Tickle L. (2000) A kinematic study of contextual effects on reaching performance in persons with and without stroke: influences of object availability. Archives of Physical Medicine and Rehabilitative Medicine. Vol 81:95-101

Yokochi K, Yokochi M, Kodama K. (1995) Motor function of infants with spastic hemiplegia. Brain Development. Vol 17(1):42-48

Appendix A: Questionnaire

QUESTIONNAIRE FOR PARENTS/CAREGIVERS:

Thank-you for taking time to answer this questionnaire regarding constraint-induced movement therapy (CIMT). Please cross the appropriate answer to each question.

1. Did any of the children show irritability in wearing the CIMT? | No | Yes |
If yes, how did they demonstrate this irritability?

2. Was there ever a need to remove the CIMT during the strapping period? | No | Yes |
If yes, please state when and why the CIMT was removed.

3. Do you feel that the children benefited from CIMT? | No | Yes |
If yes, please discuss why you believe the child benefited.

4. Do you have any suggestions on how the CIMT could be improved?

Appendix B: The pilot study

B1. Introduction

Initially, it was the intention of this research to study hemiplegic scholars learning in Western Cape Schools for the Physically Disabled. Fifteen schools were contacted and asked whether they would agree to participate in the study. All the schools contacted refused to allow their scholars to participate due to concerns about the children's frustrations and decreased level of independence whilst wearing the CIMT, as well as the increased pressure on teachers and therapists to supervise these children. It was therefore decided to recruit hemiplegic patients receiving outpatient care at RCWMCH.

Therefore, it was decided that hemiplegic patients between the ages of two and five years attending out-patient physiotherapy at RCWMCH would be eligible for participation in the study. This age group was chosen as they are below school-age. In addition, at two years of age children of normal development have mastered most of their gross motor skills. They are also starting to refine their fine hand function tasks (Exner, 1989) Therefore, the change in hand function over two weeks of intervention will be more likely due to the CIMT, than due to natural progression in the development of hand skills (see literature review.)

A pilot study was performed before formal data collection commenced in order to allow the researcher to test the methodology that was discussed in Chapter 3. It was also used to understand the practicalities of the study and to determine any shortfalls in the therapy or assessment measures.

B2. Methodology

B.2.1. Study design

The pilot study was a prospective, single blinded, randomized controlled study design.

B.2.2 Study patients

Four patients were randomly selected, using a random number table, from the 25 patients who had agreed to participate in the study. These patients were randomly divided into two groups using the sealed envelope system – A and B groups. These patients were then contacted telephonically and via post to inform them of the date when they were required to be at Red Cross Children's Hospital.

B.2.3 Aims of pilot study

The aims of the pilot study were to:

- evaluate the proposed study design that was discussed in Chapter 3;
- understand the practicalities of the study; and
- determine any shortfalls in the therapy or assessment measures.

B3. Procedure

B.3.1. Patient assessments

Subjects were assessed by the researcher who was blinded to the group allocation. Subjects were initially assessed before the start of the therapy sessions and then two weeks thereafter. The Peabody Developmental Fine Motor Scale (2^{nd} edition) was used to assess the upper limb and hand function of the hemiplegic upper limb and the VICON apparatus was used to assess the kinematic analysis of the reaching movement of their hemiplegic upper limbs. The kinematic analysis took place at the University of Cape Town Sports Science Institute in Cape Town

B.3.2 Treatment intervention

Subjects were asked to attend physiotherapy every day for ten working days from one o'clock to four o'clock. The sessions were facilitated by a Red Cross physiotherapist (not the researcher) who had experience in treating children with hemiplegia and had been trained by the researcher in constraint-induced movement therapy (CIMT) and shaping sessions.

All treatment sessions were planned and organized beforehand in order to standardize the treatment. The CIMT and NDT based physiotherapy groups underwent similar tasks, with

treatment sessions consisting of activities of daily living (ADL), gross motor and fine motor activities. Patients in the CIMT group had their non-affected hand restrained using the constraint-induced movement apparatus.

Table B1: Treatment session layout

Treatment time	***Activities***
1:00-1:30	Play session - unstructured play session
1:30 – 1:40	ADL session e.g. Removing shoes and socks
1:40 -2:10	Gross motor exercises e.g. Weight bearing on arm, throwing and bouncing ball etc.
2:10 -2:50	Fine motor exercises e.g. Threading beads, finger painting, colouring in pictures etc.
2:50- 3:00	ADL session e.g. Washing hands
3:00 – 3:15	Tea interval - children encouraged to hold cup and biscuits in affected hand
3:15 -3:35	Gross motor exercises
3:35 -3:55	Fine motor exercises
3:55 – 4:00	ADL e.g. Replacing shoes and socks

ADL – activities of daily living

In the CIMT group, parents were allowed to remove the CIMT if the child needed to go the bathroom. If a child was uncooperative and became anxious wearing the CIMT, the facilitator could remove the CIMT for a few minutes and then reapply it. This process could be repeated three times, if thereafter the child was still non-compliant the CIMT would be removed and the child would be encouraged to continue with the exercises using the hemiplegic hand. The child would be asked to return the next day.

Parents received transport money to bring their child to the hospital everyday and physiotherapy sessions were free of charge for the research participants.

B4. Results

B.4.1 Study sample

One of the children in the NDT based physiotherapy group acquired pneumonia and was removed from the study – this left only one study participant for the NDT based physiotherapy pilot group. One of the children in the pilot CIMT group showed no clinical signs of hemiparesis on the Peabody Developmental Fine Motor Scale and was therefore excluded from the trial (see Table 4.2 for subject details).

Table B2: Table of subjects

Gender	Age	Hemi side	ICQ/Cong	Outcome
M	3 yrs 6m	Right	Congenital	Included
M	4 yrs 2 m	Right	Congenital	Included
F	3 yrs 3m	Left	Congenital	Excluded - pneumonia
M	4 yrs 10 m	Left	Congenital	Excluded-not hemiplegic

Therefore, only two subjects participated in the pilot study. The first patient, JV, (age = 47 months, mild right hemiplegic) was allocated to the NDT based physiotherapy group. JV was born at 32 weeks and had a birth weight of 1.794 kgs. Unfortunately, no CT scan results were available.

The other subject, SS, (age = 29 months, moderate right hemiplegic) was allocated to the CIMT group. SS was born at term and had a birth weight of 3.28 kgs. His CT scan results showed an old left middle cerebral artery infarct and dilatation of the left lateral ventricle.

B.4.2 Therapy sessions

The NDT based physiotherapy subject attended eight of the ten treatment sessions in total due to social reasons and was noted to become tired and irritated towards the end of the sessions. For most of the sessions, he was only able to tolerate two and a half hours and thereafter would refuse to cooperate.

The CIMT subject attended six therapy sessions and refused to co-operate in any of the sessions. During the sessions he would try to remove the CIMT constantly and was extremely frustrated which lead to him screaming. The therapy sessions lasted for approximately an hour each day; however none of the required therapy techniques were performed due to poor compliance. The therapy sessions were stopped after six days of attempting to gain co-operation.

B.4.3 Peabody Results

The NDT based physiotherapy subject, JV, showed an improvement in his PDFMS fine motor quotient (FMQ) score. On initial assessment it was 73 FMQ and improved to 97 FMQ on post therapy assessment. His grasp raw score improved from 42 to 48, and his visual motor integration improved from 116 to 125. JV did not arrive for his one month follow up appointment (table 4.3).

The CIMT subject, SS, scored a 46 FMQ on the PDFMS. This score indicated that his raw scores for grasp and visual motor integration were five and 17 respectively. Due to poor co-operation and behavioural issues he did not participate in any treatment sessions and he was not reassessed.

Table B3: Subject results

Subject	**Age (months)**	**Grasp-pre**	**Grasp-post**	**VMI-pre**	**VMI-post**	**FMQ-pre**	**FMQ-post**
Control (JV)	47 m	42	48	116	125	73	97
CIMT (SS)	29m	5	-	17	-	46	-

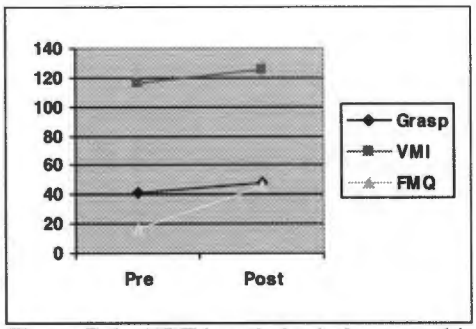


Figure B 1: NDT based physiotherapy subject's PDFMS plot graph

B.4.4 Vicon Analysis

Kinematic analysis was only completed on the NDT based physiotherapy subject, JV, as the CIMT subject refused to co-operate during the testing. Initially JV's active range of elbow extension at the end of the reaching movement was 139.39 degrees. After two weeks of therapy, his active range of elbow extension was 158.28 degrees. His change in trunk rotation also decreased from 40.98 degrees initially to 21.607 degrees after the two weeks of therapy (Figure 2).

The patient's movement time was captured as being 0.975 seconds before the treatment and 4.1667 seconds after the treatment. This, however, is not a true reflection of the movement time as the data capturing started late in the reaching movement.

The subject's change in movement units (acceleration and deceleration during a reaching movement) were also viewed before and after the two weeks of therapy. The movement unit appeared to be less smooth after the intervention.

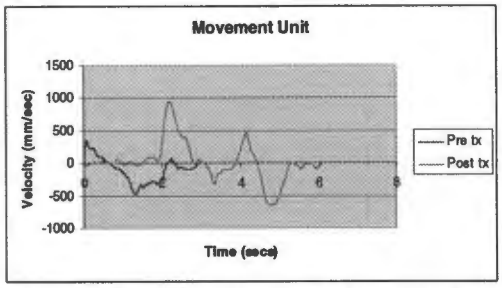


Figure B2: Showing changes in the movement unit from pre to post treatment.

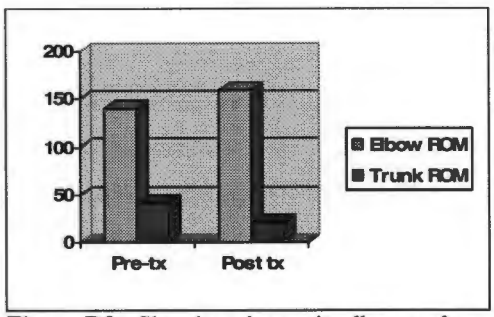


Figure B3: Showing change in elbow and trunk range of movement

B.4.5 Questionnaire

A questionnaire (see Appendix A) was completed by both caregivers at the end of the various sessions and parent's comments to the researcher were also documented. The caregiver of the NDT based physiotherapy subject, JV, felt that JV's hand function had improved after the two weeks of therapy. The caregiver did, however, feel that he became tired and distracted after three hours of therapy.

The CIMT subject's mother did not feel that her child benefited from the treatment and was extremely frustrated due to the CIMT. She also felt that the tasks were not age-appropriate enough for the child. She acknowledged that her child did have some behavioural issues that needed to be addressed and that may have affected the way in which he tolerated the CIMT apparatus.

B5. Discussion

The NDT based physiotherapy subject who underwent two weeks of NDT therapy showed an overall improvement in his PDFMS scores – which indicates that his affected hand function had improved over the two weeks. He also showed an increase in elbow extension and a decrease in trunk rotation - both of these results are very promising as children with hemiplegia tend to reach with flexion of the elbow, and compensate for this by rotating the trunk towards the object. JV's increase in elbow extension with a decreased trunk rotation shows an increase in his functional quality of movement after the therapy and also shows that he did not need to compensate as much with his trunk in order to achieve a functional goal when reaching. The caregiver also seemed to appreciate the improvement in her child.

The child who underwent CIMT was younger than JV and was also struggling with behavioural issues which might have impacted on his tolerance whilst wearing the restraint. As discussed earlier, this lack of co-operation and poor behaviour led to the researcher withdrawing the patient from the study as the CIMT protocol was not been followed effectively. This does, however, raise some questions about the compliance of children who are restrained and the underlying frustration that these children have due to being restrained.

It was also interesting to note that in both cases the patients were unable to tolerate a three hour therapy session and both caregivers noted tiredness in their children. This raises questions regarding other studies that are being performed at other centres where children are being restrained for six hours a day. It was also noted that some exercises were too advanced for the children in the study – this could also have led to frustration while attempting the task or even lack of interest in the task, which could possibly have placed a detrimental effect on the child's motor learning and therefore new skill acquisition of the affected hand.

It was not the aim of this pilot study to make conclusions regarding the use of CIMT versus NDT based physiotherapy. However, there may be some improvement with an intense course of therapy.

B6. Outcomes of pilot study

The results of the pilot study appeared to show some positive results from an intensive period of physiotherapy and most feedback appeared to be positive regarding the intense two week therapy course. It was therefore decided to continue with the research trial, in order to attempt to credit or discredit these findings.

As a result of the findings of the pilot study, the following alterations were made to the methodology:

- Children will only attend therapy for two hour sessions every day for 10 working days.
- Children will be randomly allocated into NDT based physiotherapy groups and CIMT groups and then divided into therapy groups according to age.
- Tasks will be more age-appropriate for the younger children.
- If a child refuses to comply with the CIMT for two days, the child will be removed from the study. A questionnaire will be given to the caregiver/parent to discuss possible reasons for non-compliance.

Appendix C 1: Informed consent - English Version

Research Topic:
Investigating the effects of constraint induced movement therapy in children with hemiplegia between the ages of two to five years of age.

Basic description of the study:
The study is looking at whether restraining (constraint strapping) your child's strong hand, will help to improve your child's weak hand.

Methodology:
The children, who are included in the study, will be divided into two groups: One group will receive constraint strapping five times a week for two hours each session, for two weeks. The other group will also attend the out-patient physiotherapy department, for the same period of time but will receive no strapping of their strong hand. After two weeks, the children will continue with their usual routine. They will be tested again after 1 month to see whether the weaker hand has improved with the strapping.

Payments:
The researcher will pay for the transport to and from the hospital for the physiotherapy sessions. The researcher will also pay for the cost of the physiotherapy sessions. No other money will be given to the parents or children for being involved in the study.

Benefits/Risks
The study aims to improve the quality and type of physiotherapy given to children with hemiplegia in the future. This will hopefully help the children to use their weaker hand more. The treatment in this study might not directly help your child, however it may help children who are similar to your child in the future. There are no known risks in the treatment of your child during the study.

The treatment of your child and the relationship between yourselves and the physiotherapist will not be affected if you decide that you do not want to participate in the study. If at any time in the study you no longer wish to participate, for any reason, then you will be welcome to withdraw and it will not impact on your relationship with the physiotherapist or future therapy.

I ..... (legal guardian / parent) of ..... Hereby give informed consent for the child in my care to participate in the study.
Date .....
Signed.....

If you have any further enquiries or questions, please contact Mrs Esther Geretto at the physiotherapy department at Red Cross Children's Hospital. Phone no: 021 –658 5033

Appendix C 2: Informed consent – Afrikaans Version

Navorsing Onderwerp
Die ondersoek na die effekte van die gebruik van 'n beperkingsaparaat om beroerte/hemiplegiese kinders tussen twee and vyf jaar oud.

Basiese beskrywing van die studie
Die ondersoek kyk na die gebruik van 'n berperkingsaparaat wat die gesonde hand van die kind vasmaak. Die doeluit is om die swakker hand beter te laat funksioneer.

Metodiek
Deelneemende kinders sal opgedeel word in twee groepe. Díe groepe sal fisioterapie bywoon daagliks vir twee ure oor twee weke. Die een groep sal die beperkingsaparaat gebruik, maar die ander groep nie. Na die twee weke sal die kinders hulle normale roetine herneem. Na 'n maand se tyd sal die kinders herevalueer word om enige blywende uitwerkings van die beperkingsaparaat te beperk.

Betalings
Tydens hierdie studie sal die vervoer na en van die hospitaal vir die doel van fisioterapie deur die navorser betaal word. Die koste van die behandeling sal ook deur die navorser verskaf word. Geen ander betalings vir die deelneming in hierdie studie sal betaal word nie.

Voordele/Gevare
Die doeluit van die studie is om die hoedonigheid en metode van die behandeling van hemiplegiese kinders to verbeter, dat hulle meer funksioneel word. Die studie sal dalk nie direk u kind voordeel nie, maar dit sal hoopeliks ander kinders voorreg gee na die toekoms. Daar bestaan geen voorspelbare gevare in die studie of in die behandeling van die kind nie.
As u besluit om nie in hierdie studie deel to neem nie, sal dit nie u kind se fisioterapie behandeling of u verhouding met die fisioterapeat negatief beinvloed of verander nie. U verhouding met die fisioterapeut en toekomstige behandeling van u kind sal ook nie negatief beinvloed wees nie as u dalk kies om tydens die studie te ontrek nie.

Ek _____ wettige voog/ouer van _____ gee toestemming vir die kind in my sorg om deel to neem ann hierdie studie.

Datum_____
Handtekening_____

As u enige navrae het, kontak asseblief Mev Esther Geretto by die fisioterapie department van die Rooi Kruis Hospitaal vir Kinders. Telefoon Nommer: 021-658 5033

Appendix C 3: Informed consent – Xhosa Version

Isihloko esiphandeiweyo:
Ukuphanda ngeziphumo zokubotshwa (ukubhandeshwa) kubantwana abanesandla esinye eqinga sebenziyoabaphakathi kweminyak emithathu nemihlanu.

Eyona Nkcazelo yezizifundo:
Ezizifundo zijonga ukuba okukubotshwakwabantwana bonesandla esingasebenziyo (esichaphazelekileyo) sakunceda ukusebenze ngakumbi kwesisandla engasebenziyo.

Inkqubo
Abantwana abangamashumi amane bazakonyulwa kwisibhedlele somnqamlezo obomvu kwicandelo lozokolulwa. Abantwana bazakohlulwa babeziziqingatha ezimbini: Enye igroup izakufumana ukubotshwa kathathu evekini ngeyure ezimbini kweseshini nganye, kwiveki ezintatu. Enye igroup izakuza kwelacandela kathathu evekini iyure ezimbini kwiseshini nganye, kodwa bono abayikubotshwa. Emva kweveki ezintathu, abantwana bazakwehla kulendlela iqhelekileyo. Bayakujongwa emva kwenyanga ezimbini ukuyonga ukuba okukubotshwa kwesisandla kuthathe ixesha elingekanane.

Intlawulo
Ngelixesha lezizifundo isithuthi ukusuka ekhaya nasesibhedlele for imithambo izakuhlwa ngumphandi. Ixabiso lemithambo nayo izakuhlalwa ngumphandi. Ixabiso lemithambo nayo izakuhlawulwa ngumphandi. Akukho ntlawulo yimbi ezakunikwa ngokuthatha inkxaxheba kwezizifundo.

Inzuzo/ Umngcipheko
Injongo zezifundo kukunceda ukuphuhlisa inkangeleko enkiwa abantwana abanesandla esinye esingasebenziyo kubom obuzayo ukuzamela bona bakwazi ukusenbenzisa ngakumbi.Ngexesha ezizifundo zingamnceda umntwana wakho. Iyakuba yinzuzo kubantwana abanesandla esingasebenziyo embmini.

Unyango lomntwana wakho nonxumelelwano phakathi kwakho nomoluli aliyikutshintsha, okanye iphazamiseke., Ukuba kgqiba ukuba akufuni ukuthatha inkxaxhebe kwezizifundo. Ukuba kungabikho uqhagamshelo phakathi kwakho nomoluli womnthabo.

Mna .....(umngcini mntana ngokusesikweni, mzali) ka..... Ndiyavuma ukunika isivemelwano nomtwana ukuthatha inxaxheba kwezizifundo.
Umhla.....
Tyikitya.....

Ukuba unemibuzo engaphaya, nceda qhaqamshelana no Nkosisakazi Esther Geretto kwlcandelo lezomoluko kwesisbhedlele sase Red Cross. Umnxeba: (021) 658 5033

Appendix D: Movement Units

D.1: Velocity profiles for individuals in the CIMT group

The individual velocity profiles showing the movement units for the patients in the CIMT group are shown in the figures below. The blue line represents the velocity profile before therapy (pre tx) and the pink line represents the velocity profile after therapy (post tx).

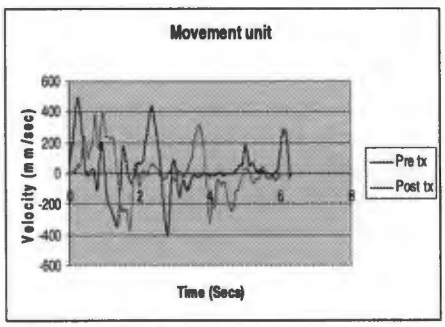


Figure D 1: Patient A

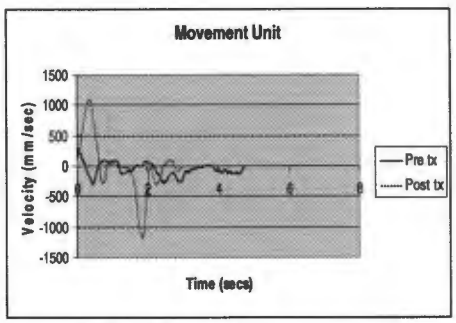


Figure D 2: Patient B

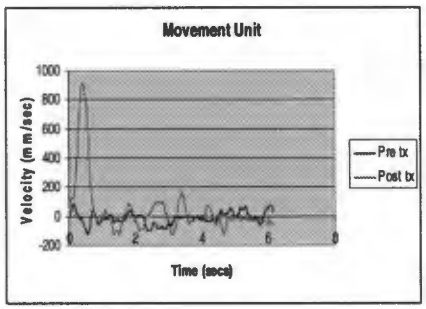


Figure D 3: Patient C

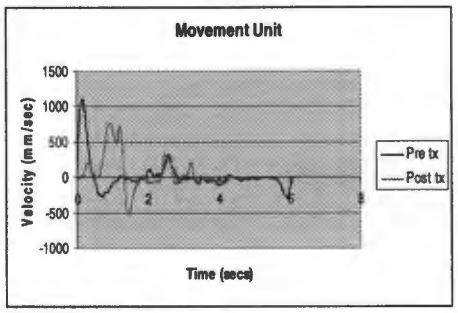


Figure D 4: Patient D

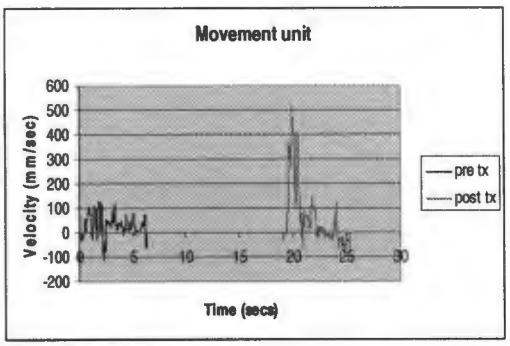


Figure D 5: Patient E

D.2: Velocity profiles for individuals in the NDT based physiotherapy group

The individual velocity profiles showing the movement units for the patients in the NDT based physiotherapy group for are shown in the figures below. The blue line represents the velocity profile before therapy (pre tx) and the pink line represents the velocity profile after therapy (post tx).

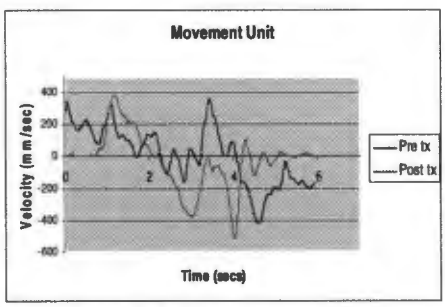


Figure D 6: Patient A

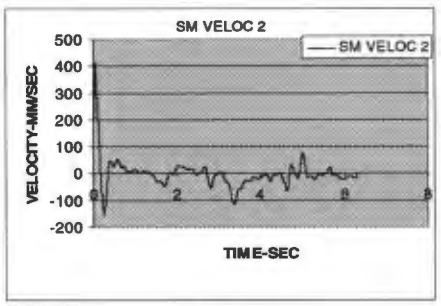


Figure D 7: Patient B (pre tx)

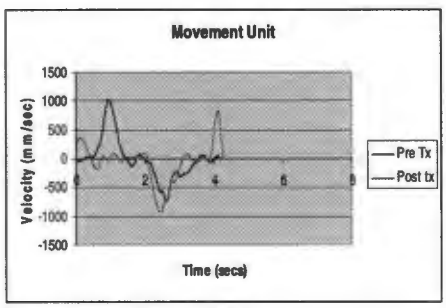


Figure D 8: Patient D

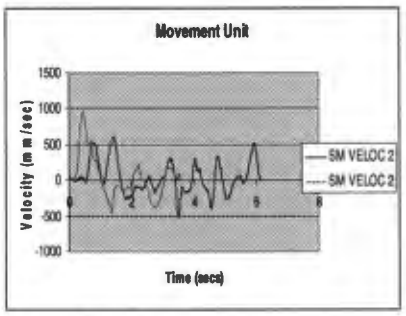


Figure D 9: Patient E

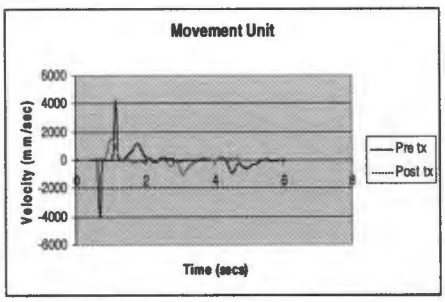


Figure D10: Patient F

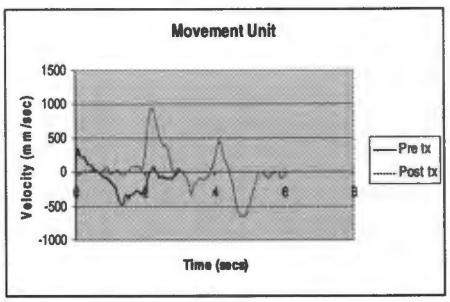


Figure D 11: Patient G

Appendix E: Group physiotherapy programme

Please note: The children in the CIMT need to wear the mitt for all activities. The children in the NDT based physiotherapy should be encouraged to use their hemiplegic upper limb, but may use their non-affected upper limb for assistance and for bilateral hand activities.

1. ADL (1:00-1:10 pm):

Removal of shoes, socks and jersey. Caregiver may give assistance as required.

2. Preparation activities:

2.1 Passive movements (1:10 – 1:20 pm):

Facilitator to demonstrate passive movements. Caregiver to do passive movements on their child.

These movements include: -
- mobilization of scapula – retraction and protraction
- glenohumeral joint – shoulder flexion and shoulder abduction
- shoulder extension and shoulder adduction
- elbow joint – flexion, extension, supination , pronation
- wrist –flexion, extension, radial and ulnar deviation
- fingers – MCP joints: flexion and extension, abduction and adduction
- PIP and DIP joints: flexion and extension
- Thumb – opposition, flex and extension, adduction and abduction

2.2 Tactile awareness (1:20 – 1:40) –Finger painting

Sitting at table with caregiver, feet flat on the floor.

Children to place their fingers in the paint and draw a picture on the white paper provided.

3. Weight bearing exercises (1:40 – 2:00)

3.1 Hitting balloon to mother

Propped prone lying and hitting balloon to caregiver with the non-affected hand – which encourages weight bearing through their affected upper limb. They can also move up to side sitting (with weight bearing through their hemiplegic upper limb) and hitting the balloon in this position with non-affected hand.

Thereafter, the child should be encouraged to hit the balloon with their affected upper limb to the parent/caregiver.

3.2 Pushing blocks and making a mini course for push toys

There will be a number of blocks in the room. The children should be encouraged to lift and move them to make a mini obstacle course.

3.3 Rolling ball up wall to a specific point on the wall – using gold stars

The child will be asked to roll a ball up the wall – either with the affected hand or bilateral hands to the first gold star. On the wall there will be a number of gold stars that the child has to try get the ball to.

4. ADL - Washing hands (2:00-2:05):

They may remove CIMT for this activity. The children should sit at a table with a water bowl in front of them. The child needs to take the dry cloth with affected hand and place it in the water. Thereafter the child needs to squeeze the water out of the wash cloth with their hemiplegic hand a few times and then wash hands. The child must then dry his hands with towel after washing them.

5. Tea interval (2:05 – 2:15):

Children and parents will receive juice and biscuits. The child should be encouraged to hold the cup and hold biscuits in their affected hand.

6. In-hand manipulation tasks (2:15 -2:50)

6.1 Tearing newspaper

The children can be seated on the floor with the newspaper.

They should tear the newspaper with their affected hands and crumple the torn newspaper into balls. They then need to throw the newspaper into a container with their affected hand. .

6.2 Collecting objects

Child sitting at table, with their feet flat on the floor.

There will be objects placed in a bowl of water. Each child needs to take out the object and place it in into another container using their affected hand.

6.3 Joining the dots on paper

Child sitting at table with feet firmly on the floor.

Each child is given a page with dots on. The child is to grasp a large crayon in their affected hand and attempt to complete the dots; the caregiver may offer some assistance in this regard. The child can then colour in the picture.

7. ADL (2:50 – 3:00)

Child to replace shoes and socks using the affected hand. The caregiver may give assistance if this is required.

Appendix F: Data Analysis

Table F 1: Non-Parametric Independent Group Comparison *for age* using Pearson and Spearman correlation

Age and....	No cases	Pearson's r (Correlations Coefficient)	R-Square	t	p	Spearman's Rank Correlation Coefficient
Grasp-baseline	12	-0.2090	0.0437	-0.6757752	**0.515**	-0.2201
VMI-baseline	12	0.2136	0.0456	0.6915834	**0.505**	0.2425
FMQ baseline	12	-0.3849	0.1482	-1.318784	**0.217**	-0.4096
Elbow baseline	12	0.2815	0.0792	0.9275185	**0.376**	0.2035
Trunk ROM baseline	12	-0.1173	0.0138	-.3734374	**0.717**	0.0842
Movement baseline	12	0.2667	0.0711	.8751966	**0.402**	0.2456
MU's pre	12	0.2109	0.0445	0.6823456	**0.511**	-0.0141
Max v	12	0.2785	0.0776	.9171262	**0.381**	0.4421
Ratio	12	-0.1561	0.0244	-.4999185	**0.628**	-0.1054

Table F 2: Non-Parametric Independent Group Comparison for *gender* using Mann-Whitney U

Gender and....	n	Mean rank-female	Mean rank-male	Mann-Whitney U statistic	Z	2-tailed p
Grasp-baseline	12	6.5	6.5	16	-0.085	0.932
VMI-baseline	12	8.38	5.56	23.5	1.189	0.234
FMQ baseline	12	6	6.75	18	0.255	0.799
Elbow baseline	12	6.75	6.38	17	.085	0.932
Trunk ROM baseline	12	7.25	6.13	19	0.425	0.671
Movement baseline	12	8.25	5.63	23	1.104	0.269
MU's pre	12	7.75	5.88	21	0.764	0.445
Max v	12	7.5	6	20	0.594	0.552
Ratio	12	7.63	5.94	20.5	0.679	0.497

Table F 3: Non-Parametric Independent Group Comparison for *hemi side* using Mann-Whitney

Hemi side and....	n	Mean rank-left	Mean rank-right	Mann-Whitney U statistic	Z	2-tailed p
Grasp-baseline	12	4.	7.75	26	1.613	0.107
VMI-baseline	12	5	7.25	22	0.934	0.35
FMQ baseline	12	3.75	7.88	27	1.783	0.075
Elbow baseline	12	6.5	6.5	16	-0.085	0.932
Trunk ROM baseline	12	6	6.75	18	0.255	0.799
Movement baseline	12	7.5	6	20	0.594	0.552
MU's baseline	12	7.25	6.13	19	0.425	0.671
Max v	12	8.5	5.5	24	1.274	0.203
Ratio	12	7.25	6.13	19	0.425	0.671

Table F 4: Non-Parametric Independent Group Comparison for *Birth Hx* using Kruskal-Wallis

Birth History and....	n	Kruskal Wallis - H	p-value
Grasp-baseline	12	0.21	0.901
VMI-baseline	12	0.5	0.778
FMQ baseline	12	0.35	0.838
Elbow baseline	12	0.41	0.814
Trunk ROM baseline	12	0.68	0.711
Movement baseline	12	3.72	0.157
MU's pre	12	0.54	0.765
Max v	12	4.34	0.115
Ratio	12	1.71	0.427

Table F 5: Statistical analysis for within group variables for ALL patients using Wilcoxon's test

Outcome measure	Difference between pairs	Wilcoxon	Rank sum	Mean rank	Wilcoxon's W statistic	2-tailed p
Grasp baseline to two weeks	Positive	0	0.0			
	Negative	10	55.0			
						0.016
Grasp baseline to six weeks	Positive	0	0.0	-		
	Negative	6	21.0	3.50		
					0.0000	0.0313
Grasp two weeks to six weeks	Positive	2	3.0	1.50		
	Negative	1	3.0	3.00		
					3	1.0000
VMI baseline to two weeks	Positive	2	7.0	3.50		
	Negative	9	59.0	6.56		
					7	0.0186
VMI baseline to six weeks	Positive	1	1.0	1.00		
	Negative	6	27.0	4.50		
					1	0.0313
VMI two weeks to six weeks	Positive	2	5.0	2.50		
	Negative	3	10.0	3.33		
					5	0.312
FMQ baseline and two weeks	Positive	1	5.0	5.00		
	Negative	5	16.0	3.20		
					5	0.3125
FMQ baseline and six weeks	Positive	0	0.0	-		
	Negative	5	15.0	3.00		
					0	0.0625
FMQ two weeks and six weeks	Positive	1	2.0	2.00		
	Negative	2	4.0	2.00		
					2	0.7500
Elbow extension baseline and two weeks	Positive	4	26.0	6.50		
	Negative	7	40.0	5.71		
					26	0.19

Trunk rotation baseline and two weeks	Positive	6	36.0	6.00		
	Negative	5	30.0	6.00		
					36	0.172
Movement time baseline and two weeks	Positive	7	Other – 29 36.0	5.14		
	Negative	3	Other – 26 30.0	7.50		
					36	0.19
Movement unit baseline and two weeks	Positive	6	32.5	5.33		
	Negative	3	13.0	4.33		
					32	0.16
Peak velocity baseline and two weeks	Positive	3	10.0	3.33		
	Negative	7	45.0	6.43		
					10	0.0840
Ratio of movement unit to time-baseline and two weeks	Positive	4	19.0	4.75		
	Negative	6	36.0	6.00		
					19	0.24

Table F 6: Affects of change in variables on outcome measures

	n	Rank sum	Mean rank	U	Mann-Whitney U statistic	2-tailed p
Gender:						
Grasp 0 - Grasp 2 by Sex	**n**	**Rank sum**	**Mean rank**	**U**	**Mann-Whitney U statistic**	**2-tailed p**
f	4	28.0	7.00	14.0		
m	8	50.0	6.25	18.0	14	0.8081
VMI 0 - 2 by Sex						
f	4	14.5	3.63	27.5		
m	8	63.5	7.94	4.5	27.5	0.0727
FMQ 0 -2 by Sex						
f	4	14.5	3.63	27.5		
m	8	63.5	7.94	4.5	27.5	0.0727
ROM elb 0-2 by Sex						
f	4	17.0	4.25	21.0		
m	7	49.0	7.00	7.0	21	0.2303
ROM tx 0-2 by Sex						
f	4	20.0	5.00	14.0		
m	6	35.0	5.83	10.0	14	0.7619
MT 0-2 by Sex						
f	4	27.0	6.75	11.0		
m	7	39.0	5.57	17.0	11	0.6485
MU 0-2 by Sex						
f	4	19.0	4.75	15.0		
m	6	36.0	6.00	9.0	15	0.6095
Max v 0-2 by Sex						
f	4	20.0	5.00	14.0		
m	6	35.0	5.83	10.0	14	0.7619
Ratio 0-2 by Sex						
f	4	27.0	6.75	7.0		
m	6	28.0	4.67	17.0	7	0.3524
Birth History						
Grasp 0 - Grasp 2 by BHx						
prem	5	41.5	8.30	3.5		
term	6	24.5	4.08	26.5	3.5	0.0519
VMI 0 - 2 by BHx						
prem	5	40.0	8.00	5.0		
term	6	26.0	4.33	25.0	5	0.0823
FMQ 0 -2 by BHx						
prem	5	35.0	7.00	10.0		
term	6	31.0	5.17	20.0	10	0.4286
ROM elb 0-2 by BHx						
prem	4	25.0	6.25	9.0		
term	6	30.0	5.00	15.0	9	0.6095
ROM tx 0-2 by BHx						
prem	4	14.0	3.50	16.0		
term	5	31.0	6.20	4.0	16	0.1905

MT 0-2 by BHx						
prem	4	33.0	8.25	1.0		
term	6	22.0	3.67	23.0	1	0.0190
MU 0-2 by BHx						
prem	4	14.5	3.63	15.5		
term	5	30.5	6.10	4.5	15.5	0.2857
Max v 0-2 by BHx						
prem	4	30.0	7.50	0.0		
term	5	15.0	3.00	20.0	0	0.0159
Ratio 0-2 by BHx						
prem	4	20.0	5.00	10.0		
term	5	25.0	5.00	10.0	10	1.0000
HEMI SIDE						
Grasp 0 - Grasp 2						
L	4	25.5	6.38	16.5		
R	8	52.5	6.56	15.5	16.5	0.9333
VMI 0 - 2						
L	4	32.0	8.00	10.0		
R	8	46.0	5.75	22.0	10	0.3677
FMQ 0 -2 by Hemi side						
L	4	22.0	5.50	20.0		
R	8	56.0	7.00	12.0	20	0.5697
ROM elb 0-2 by Hemi side						
L	4	29.0	7.25	9.0		
R	7	37.0	5.29	19.0	9	0.4121
ROM tx 0-2 by Hemi side						
L	3	14.0	4.67	13.0		
R	7	41.0	5.86	8.0	13	0.6667
MT 0-2 by Hemi side						
L	4	23.0	5.75	15.0		
R	7	43.0	6.14	13.0	15	0.9273
MU 0-2 by Hemi side						
L	3	17.5	5.83	9.5		
R	7	37.5	5.36	11.5	9.5	1.0000
Max v 0-2 by Hemi side						
L	3	11.0	3.67	16.0		
R	7	44.0	6.29	5.0	16	0.2667
Ratio 0-2 by Hemi side						
L	3	9.0	3.00	18.0		
R	7	46.0	6.57	3.0	18	0.1167
AETIOLOGY						
Grasp 0 - 2 by Acq/non						
acq	5	31.5	6.30	8.5		
non	5	23.5	4.70	16.5	8.5	0.5476
VMI 0 - 2 by						

Acq/non						
acq	5	20.0	4.00	20.0		
non	5	35.0	7.00	5.0	20	0.1508
FMQ 0 -2 by Acq/non						
acq	5	20.5	4.10	19.5		
non	5	34.5	6.90	5.5	19.5	0.2222
ROM elb 0-2 by Acq/non						
acq	5	16.0	3.20	19.0		
non	4	29.0	7.25	1.0	19	0.0317
ROM tx 0-2 by Acq/non						
acq	5	22.0	4.40	8.0		
non	3	14.0	4.67	7.0	8	1.0000
MT 0-2 by Acq/non						
acq	5	28.0	5.60	7.0		
non	4	17.0	4.25	13.0	7	0.5556
Max v 0-2 by Acq/non						
acq	5	19.0	3.80	11.0		
non	3	17.0	5.67	4.0	11	0.3929
Ratio 0-2 by Acq/non						
acq	5	22.0	4.40	8.0		
non	3	14.0	4.67	7.0	8	1.0000

Table F 7: Difference in scores of outcome measures between the CIMT and NDT based physiotherapy group

Outcome measure	n	Rank sum	Mean rank	Kruskal-Wallis statistic	p
Grasp-raw (pre) by No of pts(A)					
a	5	24.5	4.90		
b	7	53.5	7.64	1.70	0.1923
Grasp-raw (post) by No of pts(A)					
a	5	27.5	5.50		
b	7	50.5	7.21	0.66	0.4152
grasp raw - 1m by No of pts(A)					
a	2	5.5	2.75		
b	6	30.5	5.08	1.47	0.2260
VMI raw-pre by No of pts(A)					
a	5	30.5	6.10		
b	7	47.5	6.79	0.11	0.7449
VMI raw-post by No of pts(A)					
a	5	25.5	5.10		
b	7	52.5	7.50	1.31	0.2531
VMI raw- 1 m by No of pts(A)					
a	2	5.0	2.50		
b	6	31.0	5.17	1.80	0.1798

FMQ-pre tx by No of pts(A)					
a	5	25.5	5.10		
b	7	52.5	7.50	1.32	0.2506
FMQ-post tx by No of pts(A)					
a	5	24.0	4.80		
b	7	54.0	7.71	1.96	0.1615
FMQ -1 m by No of pts(A)					
a	2	7.5	3.75		
b	6	28.5	4.75	0.26	0.6128
ROM:elb-pre by No of pts(A)					
a	5	33.0	6.60		
b	6	33.0	5.50	0.30	0.5839
ROM:elb-post by No of pts(A)					
a	5	36.0	7.20		
b	7	42.0	6.00	0.32	0.5698
ROM:change trunk-pre by No of pts(A)					
a	5	23.0	4.60		
b	6	43.0	7.17	1.63	0.2012
ROM:change trunk-post by No of pts(A)					
a	5	35.0	7.00		
b	7	43.0	6.14	0.16	0.6847
Movt time-pre by No of pts(A)					
a	5	28.0	5.60		
b	6	38.0	6.33	0.13	0.7150
Movt time-post by No of pts(A)					
a	5	31.0	6.20		
b	7	47.0	6.71	0.06	0.8075
MU-pre by No of pts(A)					
a	5	41.0	8.20		
b	6	25.0	4.17	4.11	0.0427
MU-post by No of pts(A)					
a	5	36.5	7.30		
b	6	29.5	4.92	1.43	0.2321
Max v-pre by No of pts(A)					
a	5	23.0	4.60		
b	6	43.0	7.17	1.63	0.2012
Max v-post by No of pts(A)					
a	5	20.0	4.00		
b	6	46.0	7.67	3.33	0.0679
1 MU:movt time-pre by No of pts(A)					
a	5	36.5	7.30		
b	6	29.5	4.92	1.41	0.2343

1 MU:movt time-post by No of pts(A)					
a	5	32.0	6.40		
b	6	34.0	5.67	0.13	0.7150

Table F 8: Differences in changes of scores for outcome measures between the CIMT and NDT based physiotherapy group

	n	Rank sum	Mean rank	U	Mann-Whitney U statistic	2-tailed p
Grasp 0 - Grasp 2 by no						
a	5	39.5	7.90	5.5		
b	6	26.5	4.42	24.5	5.5	0.1255
Grasp 2-Grasp 6 by no						
a	2	6.5	3.25	8.5		
b	6	29.5	4.92	3.5	8.5	0.6429
Grasp 0 to Grasp 6 by no						
a	2	11.5	5.75	3.5		
b	6	24.5	4.08	8.5	3.5	0.6429
VMI 0 - 2 by no						
a	5	27.0	5.40	18.0		
b	6	39.0	6.50	12.0	18	0.6623
VMI 2- 6 by no						
a	2	10.0	5.00	5.0		
b	6	26.0	4.33	7.0	5	0.8571
VMI 0 to 6 by no						
a	2	12.0	6.00	3.0		
b	6	24.0	4.00	9.0	3	0.4286
FMQ 0 -2 by no						
a	5	23.0	4.60	22.0		
b	6	43.0	7.17	8.0	22	0.2468
FMQ 2-6 by no						
a	2	11.5	5.75	3.5		
b	6	24.5	4.08	8.5	3.5	0.6429
FMQ 0-6 by no						
a	2	9.5	4.75	5.5		
b	6	26.5	4.42	6.5	5.5	1.0000
ROM elb 0-2 by no						
a	5	27.0	5.40	13.0		
b	5	28.0	5.60	12.0	13	1.0000
ROM tx 0-2 by no						
a	5	30.0	6.00	10.0		
b	5	25.0	5.00	15.0	10	0.6905
MT 0-2 by no						
a	5	36.0	7.20	4.0		
b	5	19.0	3.80	21.0	4	0.0952
MU 0-2 by no						

a	5	21.0	4.20	14.0		
b	4	24.0	6.00	6.0	14	0.4127
Max v 0-2 by no						
a	5	26.0	5.20	9.0		
b	4	19.0	4.75	11.0	9	0.9048
Ratio 0-2 by no						
a	5	23.0	4.60	12.0		
b	4	22.0	5.50	8.0	12	0.7302

Table F 9: Friedman's Anova for within group variables for the NDT based physiotherapy group.

Outcome measure	**n**	**Rank sum**	**Mean rank**	**Friedman's statistic**	**p**
Grasp baseline	7	8.0	1.14		
Grasp two weeks	7	13.0	1.86	5.0000	0.0253
Grasp baseline	6	7.0	1.17		
Grasp six weeks	6	11.0	1.83	4.0000	0.0455
Grasp two weeks					
Grasp six weeks					
VMI baseline	7	8.5	1.21		
VMI two weeks	7	12.5	1.79	2.6667	0.1025
VMI baseline	6	7.5	1.25		
VMI six weeks	6	10.5	1.75	1.8000	0.1797
VMI two weeks	6	8.5	1.42		
VMI six weeks	6	9.5	1.58	0.3333	0.5637
FMQ baseline	7	8.5	1.21		
FMQ two weeks	7	12.5	1.79	4.0000	0.0455
FMQ baseline					
FMQ six weeks					
FMQ two weeks	6	9.0	1.50		
FMQ six weeks	6	9.0	1.50	0.0000	1.0000
Elbow extension baseline	6	8.0	1.33		
Elbow extension two weeks	6	10.0	1.67	0.6667	0.4142
Trunk rotation baseline	6	10.0	1.67		
Trunk rotation two weeks	6	8.0	1.33	0.6667	0.4142
Movement time baseline	6	10.0	1.67		
Movment time two weeks	6	8.0	1.33	0.6667	0.4142
Movement unit baseline	5	7.5	1.50		
Movment unit two weeks	5	7.5	1.50	0.0000	1.0000
Peak velocity baseline	5	6.0	1.20		
Peak velocity two weeks	5	9.0	1.80	1.8000	0.1797
Ratio of movement unit to time-baseline	5	7.0	1.40		
Ratio of movement unit to time-two weeks	5	8.0	1.60	0.2000	0.6547

Table F 10: Friedman's Anova for within group variables for the CIMT group

Outcome measure	n	Rank sum	Mean rank	Friedman's statistic	p
Grasp baseline					
Grasp two weeks					
Grasp baseline	2	2.0	1.00		
Grasp six weeks	2	4.0	2.00	2.0000	0.1573
Grasp two weeks	2	3.5	1.75		
Grasp six weeks	2	2.5	1.25	1.0000	0.3173
VMI baseline	5	6.0	1.20		
VMI two weeks	5	9.0	1.80	1.8000	0.1797
VMI baseline	2	2.0	1.00		
VMI six weeks	2	4.0	2.00	2.0000	0.1573
VMI two weeks	2	3.0	1.50		
VMI six weeks	2	3.0	1.50	0.0000	1.0000
FMQ baseline	5	7.5	1.50		
FMQ two weeks	5	7.5	1.50	0.0000	1.0000
FMQ baseline	2	2.5	1.25		
FMQ six weeks	2	3.5	1.75	1.0000	0.3173
FMQ two weeks	2	2.5	1.25		
FMQ six weeks	2	3.5	1.75	1.0000	0.3173
Elbow extension baseline	5	7.0	1.40		
Elbow extension two weeks	5	8.0	1.60	0.2000	0.6547
Trunk rotation baseline					
Trunk rotation two weeks					
Movement time baseline	5	8.0	1.60		
Movment time two weeks	5	7.0	1.40	0.2000	0.6547
Movement unit baseline	5	9.0	1.80		
Movement unit two weeks	5	6.0	1.20	1.8000	0.1797
Peak velocity baseline	5	7.0	1.40		
Peak velocity two weeks	5	8.0	1.60	0.2000	0.6547
Ratio of movement unit to time-baseline	5	7.0	1.40		
Ratio of movement unit to time-two weeks	5	8.0	1.60	0.2000	0.6547

Table F 11: Effect size table

Data Entry							Standardised Effect Size					
Outcome Measure	Treatment Group			Control Group								
	Mean	n	SD	Mean	n	SD	Effect size	E.S corrected Hedges	Standard error of E.S estimate	Confidence interval for Effect Size		Effect size based on control group SD
										lower	upper	
Grasp pre-2	33.67	12	7.45	29.92	12	8.14	0.48	0.46	0.41	-0.35	1.27	0.46
Grasp 2-6 wks	32	8	13.06	33.67	12	7.475	-	-	-	-	-	-0.22
VMI pre-2	79.83	12	16.13	73.67	12	17.98	0.36	0.35	0.41	-0.46	1.15	0.34
VMI 2-6	76.38	8	26.56	79.83	12	16.13	-0.17	-0.16	0.46	-1.06	0.74	-0.21
FMQ 0-2	58.92	12	13.61	56.5	12	9	0.21	0.20	0.41	-0.60	1.00	0.27
FMQ 2-6	58.38	8	21.57	58.92	12	13.61	-0.03	-0.03	0.46	-0.92	0.86	-0.04
Elbow pre-2	126.4	12	15.6	121.8	11	40.79	0.15	0.15	0.42	-0.67	0.96	0.11
Trunk 0-2	34.01	12	17.03	35.4	11	24.81	-0.07	-0.06	0.42	-0.88	0.75	-0.06
Movt time	3.584	11	6.159	2.211	11	1.242	0.31	0.30	0.43	-0.54	1.14	0.31
MU	10.2	10	5.533	14	11	6.767	-0.61	-0.59	0.45	-1.46	0.29	-0.56